# REPORT RESUMES

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REORGANIZED SCIENCE CURRICULUM, 6B, A RESOURCE UNIT TO BE TAUGHT IN GRADE SIX.

MINNEAPOLIS SPECIAL SCHOOL DISTRICT NO. 1, MINN.

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THE TENTH IN A SERIES OF 17 VOLUMES, THIS VOLUME PROVIDES THE SIXTH GRADE TEACHER WITH A GUIDE TO THE REORGANIZED SCIENCE CURRICULUM OF THE MINNEAPOLIS PUBLIC SCHOOLS. THE MATERIALS ARE INTENDED TO BE AUGMENTED AND REVISED AS THE NEED ARISES. THIS VOLUME, 6B, IS ONE OF THE THREE COMPRISING THE SIXTH GRADE SUPPLEMENT, AND CONTAINS A RESOURCE UNIT ON SPACE TRAVEL. VOLUME 6C CONTAINS RELATED SECTIONS FOR SIXTH GRADE MATERIALS ENTITLED (1) BIBLIOGRAPHY, BOOKS, (2) BIBLIOGRAPHY, FILMS, AND (3) EQUIPMENT AND SUPPLIES. (DH)

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# A RESOURCE UNIT

## IV. THE UNIVERSE

## F. "SPACE TRAVEL"

TO BE TAUGHT IN
GRADE SIX

To be included in the Grade Six Supplement of the
Reorganized Science Curriculum

Minneapolis Public Schools
Science Department
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# I. OVERVIEW

The purposes of this resource unit is to help teachers as they plan a teaching unit on space travel. Many of the learning experiences overlap and are applicable to several concepts. A class will find it impossible to undertake all of the learning experiences. For convenience the concepts and learning experiences in the resource unit are organized into the following five subtopics:

1. General
2. Properties of Space - Universal Gravitation
3. Properties of Space - Near the Earth (Atmosphere)
4. Problems of Man's Existence in Space
5. Problems of Movement in Space

This space travel unit does not include a study of astronomy, weather and climate, gravitational energy, methods of determining directions near the surface of the earth, or the laws pertaining to objects in motion and at rest because this content is allocated to other grades or units. However, it may be necessary to review this content at the beginning of the unit.

## II. CONCEPTS INCLUDED IN THIS UNIT

### A. General

1. Through space travel man will discover many new things about the universe.
2. Man's existence on the earth is limited to the surface or near the surface.
3. There is less air as one moves up (or out) from the earth.
4. Space is dark (beyond the atmosphere).
5. Artificial satellites are being used by man to further his study of earth and space.
6. Anything within the solar system is known as being in interplanetary space.
7. Man is beginning to travel up or "out" into interplanetary space.
8. Anything beyond the solar system is known as being in outer space.
9. There is a very slight amount of air in outer space.
10. Nearness and farness in comparing bodies in space is relative.
11. Great distances in the universe are measured in terms of light-years, the distance which light travels in one year.
12. Units of time in space may be measured differently from the units of time on earth.
13. There are many problems which must be studied and solved before man can travel for extended periods of time in space.
14. There is great need for trained people to study the problems of space travel.
15. As more is learned about space travel, other factors may be found which may limit man's existence in space.
16. New projects related to space travel are continually being developed and evaluated in order to expand upon existing knowledge.
17. Results from one experiment in space research lead to the formulation of many other problems for study.
18. Problems in the building of space travel devices require the development of many new materials.

B. Properties of Space -- Universal Gravitation

19. Objects close to an astronomical body in space are attraced to that body.

20. In outer space, the pull of the earth would be very slight.

21. Many natural phenomena result from the pull of the earth; e.g., weight, water running downhill.

22. Weight is an important factor when planning a rocket's escape from the earth's gravity.

23. To get into interplanetary space a rocket must "push" harder than the earth pulls.

24. The harder a rocket "pushes" away from the earth, the farther it can go before it begins to fall.

25. A rocket which "pushes" hard enough can go farther than the distance beyond which the earth can pull it back.

26. It is possible to place objects out into space by starting them with enough force and speed to escape the gravity of the earth.

27. In order for an object to escape the gravity of the earth, it must reach a greater speed than that required to orbit the earth.

28. Gravity decreases as one leaves the earth, but increases as one approaches other astronomical bodies.

29. The moon "pulls" on things on the earth.

30. The gravitational pull on surface objects is greater on the earth than on the moon.

31. The closer an object is to the moon, the greater is the mutual attraction.

32. As two objects approach each other, the greater is the mutual attraction.

33. Gravitational energy is opposed with parachutes.

34. When approaching the earth, rockets and/or parachutes must be used to work against the earth's gravity to slow down the vehicle and thus prevent destructive impact.

35. To insure a safe landing on any astronomical body, the space vehicle would have to use a force against gravity to slow its descent.

C. Properties of Space -- Near the Earth (Atmosphere)

36. Air resists the force which would put an object in motion.

37. The resistance caused by air moving over an object is called air friction.

38. An object moving through air produces air friction.

39. The density (concentration) of air affects the amount of friction.

40. The density of the earth's atmosphere decreases as the distance from the earth increases.

41. As the speed of a moving object increases in the atmosphere, friction and heat increase.

42. Speed and altitude both determine the amount of friction on space vehicles.

43. The greater the air friction, the more intense the resultant heat.

44. Certain designs reduce friction.

## D. Problems of Man's Existence in Space

45. Man must be protected during space travel.

46. Man cannot exist in space without controlling his immediate environment.

47. Vehicles for space travel must provide a desirable environment for man.

48. Man is able to adapt to a slightly changed environment.

49. Man can live for a short period of time in a greatly changed environment.

50. Man has to carry his own oxygen when traveling away from the earth.

51. Due to weightlessness in space travel, man may have problems with his breathing, drinking, eating and moving.

52. Sustained weightlessness may cause many hazardous strains on the human anatomy.

53. The radiant energy from the sun may be dangerous to a man in interplanetary space.

54. Man will have to establish an artificial environment in order to survive on the surface of other astronomical bodies.

## E. Problems of Movement in Space

55. Space vehicles need to be protected against bombardment by meteors and cosmic dust.

56. Rockets must be made of materials which withstand heat and stress.

57. A rocket begins to rise very slowly because of the forces which must be overcome; e.g., inertia.

58. Space ships require many instruments to guide them.

59. High speed in space travel is desirable to cover great distances in a convenient time.

## III. INTRODUCTION TO THE UNIT

A. Brief review of astronomy

1. Show one or more of the following films: "Solar System," which presents a description of the solar system; "The Solar Family," which describes the origin of the sun and some characteristics of the planets; "Our Mr. Sun," which shows the dependence of living things on earth on the sun's energy; "Planets in Orbit," which presents an historical approach to the study of astronomy; or "Realm of the Galaxies," which provides information about the universe beyond the solar system.

2. Encourage the members of the class to revisit the Planetarium and "black light" exhibits at the Minneapolis Public Library.

3. Make a chart, mural or simple model of the solar system to show the order of the planets and their relative distances from the sun. (A modification of this class activity would be carried out by marking off the relative distances on the playground with chalk. This modification might emphasize the vastness of the distance between parts of the solar system.) Make a second representation illustrating the order and relative size of the planets and the sun. Use the chart, "Some Astronomical Facts and Approximations for Teaching," Appendix A to find information about these distances and sizes.

B. Brief preview of the unit

1. Prepare a bulletin board using current newspaper clippings or magazine articles on new satellites and efforts to put man into space.

2. Prepare a bulletin board on the new scientific discoveries being made by space research projects.

C. Related science-fiction reading or creative writing

1. Read a science-fiction story about the planets to the class. Ask the class to analyze the story and answer these questions: "What part of the story is only fiction?", "Why would some parts of the adventures be impossible?", and "What part of the story is based on fact?".

2. Near the close of the study of this unit have the class write a science-fiction story on space travel. Have the children underline the parts of the story which are scientifically accurate.

## IV. LEARNING EXPERIENCES

Concept #1 - Through space travel man will discover many new things about the universe.

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Experience A: Discovering that educated guesses cannot be substituted for exact knowledge

Materials needed:

reference materials (recent periodicals, textbooks, encyclopedias)
pencil
paper

What to do:

1. Consult many references to find descriptions of the surface of the moon. Compile a list of the descriptions.

2. Compare the descriptions to see if they all agree. Identify any parts of the descriptions which do not agree.

3. Answer these questions:

   a. Does anyone really know what the surface of the moon is like?

   b. How would it be possible to find out exactly what the moon is like?

   c. When will this information be available?

4. Repeat steps 1 - 3 for other astronomical bodies, such as Mars. At this time it might be appropriate to use the instructional film "Mars and Beyond."

**Experience B:** Finding out that no one knows some of the answers to questions about the universe

Materials needed:

pencil
paper
reference materials (periodicals, textbooks, encyclopedias)

What to do:

1. Review what you know about the universe.
2. Make two lists:
    a. What you want to know about the universe.
    b. What you want to know about each part of the universe.
3. Consult references to find the answers to the questions. Make a check mark by those questions for which answers are not found.
4. Suggest ways of finding out the answers to the questions marked with checks.

## Concept #2 - Man's existence on the earth is limited to the surface or near the surface.

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**Experience A:** Studying the conditions which limit man's existence

Materials needed:

pencil
paper
reference materials (periodicals, recent books, encyclopedias)

What to do:

1. Make a chart of all the physical conditions which make man's existence on the surface of the earth possible.
2. Consult reference materials to find data on the conditions deep within the earth.
3. Consult reference materials to find data on the conditions beyond the atmosphere.
4. Consult reference materials to find data concerning the changes in environment for which a man can adjust.
5. Make a chart listing the name of the condition, the data for the condition within the earth, the data for the condition beyond the atmosphere and the extremes of the condition to which a man can adapt. Indicate what devices are used to protect him from the extreme condition if a man cannot adapt to the condition.
6. Draw conclusions concerning the limits to a man's existence on earth.

Concept #3 - There is less air as one moves up (or out) from the earth.

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Experience A: Discussing experiences with air pressure at high altitude

Materials needed:

none

What to do:

1. Ask any child who has lived or hiked in the mountains to tell of his experience with breathing during exertion.
2. Have him explain why, if he had ridden in a car to the top of a mountain so that there had been no exertion in climbing, it was more difficult to breathe at the high elevation.
3. Explain how this provides evidence for the fact that the amount of air becomes less as the distance from the surface of the earth becomes greater.

Experience B: Discovering the relationship between air pressure and the amount of air

Materials needed:

bathroom scales
automobile tire

What to do:

1. Go to a filling station and inflate the spare automobile tire.
2. Weigh the tire while it is inflated on a bathroom scale.
3. Loosen the valve core and allow the air to escape.
4. Re-weigh the tire. Note the change in weight.
5. Explain why the air rushed out of the tire when the valve core was loosened.
6. Relate the change in air pressure to the change in weight, noting that decreased air pressure indicates less air.

Experience C: Observing an effect of a decrease in the amount of air

Materials needed:

weather balloon, 30" diameter (or as large a spherical balloon as can be purchased conveniently)
string, 10'
rubber band
marking pen

What to do:

1. Make special arrangements with the elevator operator of a very tall building to ride to the top while carrying a big balloon.
2. Inflate the weather balloon. Close the end by wrapping a rubber band around the neck many times.
3. Use the marking pen to make an "equator" line around the balloon.
4. Lay the string on top of the "equator" line and make a mark on both ends of the string to show where the two ends meet when the balloon is on the first floor. Be careful not to pull the string tight enough to squeeze the balloon.
5. Ride to the top of the building and measure the length of the string around the balloon (circumference of the balloon) again.
6. Compare the results.
7. Explain why the size of the balloon changed even though air was not added to or removed from the balloon.
8. Explain how the results give evidence that there is less air as one moves up (or out) from the earth.

Experience D: Observing a change in air pressure with a change in distance above the earth

Materials needed:

aneroid barometer

What to do:

1. Take an aneroid barometer to the basement of the school.
2. Tap it gently. Make a careful reading of the barometer.
3. Carry the barometer up to the top floor and again make a very careful reading of the barometer.
4. Note whether the two readings are identical.
5. Explain why the lower reading obtained on the top floor is an indication of less air.

## Concept #4 - Space is dark.

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### Experience A: Discovering that light can be invisible

Materials needed:

flashlight or slide projector
burette clamp
rectangular iron support
knife
carton, 12" x 18" approximately
paint, black, tempera or black "Dyanshine" shoe polish
chalkboard erasers, coated with chalk, 2
mirror, pocket
bead, white, small
wax, "Sealstik"
printed page from newspaper
black coat

What to do:

1. Cut a hole 1" in diameter through the center of one of the ends of the carton. Cut a larger hole in the other end of the box.

2. Cut off the top flaps.

3. Paint the inside of the carton with dull black paint.

4. Turn the carton on the side.

5. Set up the slide projector or mount the flashlight in a burette clamp attached to the rectangular support. Turn on the light. Adjust the light source so that the beam of light shines directly through both of the holes in the carton.

6. Close the curtains or pull the shades to make the room dark. Place a black coat or other light absorbing material in the path of the light beam beyond the box. (This will eliminate any reflection beyond the box.)

7. Observe whether the beam of light is visible within the box.

8. Hold the newspaper beside the opening in the side of the box. Attempt to read a medium sized headline of the paper from different distances to test how much light is reflected from the box. Measure the farthest distance from which the headline can be read.

Experience A (continued):

9. Hold a mirror in the beam of light within the box and observe that you can see the reflected light from the source. Remove the mirror.

10. String the bead on the black thread. Knot it to one end. Attach the other end of thread to the top of the box with wax so that the bead hangs in the beam of light.

11. Observe whether the bead is visible.

12. Relate the results to an explanation of why planets are visible.

13. Remove the string and bead.

14. Clap two chalk erasers together beside the box. Observe whether the beam of light becomes more visible when the chalk dust is in the air inside the box.

15. Explain why chalk dust makes the light beam visible. Explain whether every thing which reflects light must be a kind of mirror.

16. Hold the newspaper beside the opening in the side of the box as in step 8. Measure the farthest distance at which it is possible to read the same headline.

17. Explain why more light strikes the newspaper when chalk dust is in the air within the box.

18. Explain why the daytime sky is light. Explain why the night time sky is dark. Explain the difference. (In order for the sky to be light, particles which reflect light must be exposed to a source of light.)

19. Relate the observations to explain the fact that space is dark. (The reason that there is little light in space can be explained if it is recognized that dust particles do not exist in space and, therefore, light is not reflected. The only visible light is direct light from the sun and stars or reflected light from the planets and satellites.)

## Experience B: Observing light reflected by small particles

Materials needed:

beakers, 250 m.l.
slide projector, or flashlight
water, warm
milk
teaspoon
carton, 12" x 18", approximately
paint, black, tempera
medicine dropper

What to do:

1. Paint the inside of the carton with black tempera.
2. Fill the beaker 3/4 full with warm water.
3. Set up the projector on one side of the room, pointing it across the room into the black box (or into a black coat in the corner) for absorption.
4. Close the curtains or pull the shades to make the room dark.
5. Place the beaker of clear water in the beam of light. (It may be necessary to allow the water to stand for 2 or 3 minutes to allow most of the air bubbles to escape.)
6. View the beaker and its contents from the side; do not look towards the source of light. Observe that the water appears clear and the beam of light does not appear very distinct.
7. Add one drop of milk to the beaker. Watch carefully and observe the brightness of the drop of milk as it enters the water. Stir the mixture.
8. View the beaker's contents again. Observe the cloudy appearance of the water. Note that the light beam is now very distinct.
9. Summarize the difference in the observations. Answer the question: "Why is the beam of light more visible in milky water?"
10. Use the conclusions in step 9 to attempt to explain why space is dark.

Experience C: Discovering the intense blackness of the night sky

Materials needed:

none

What to do:

1. Lie down on the grass in the backyard and look up at the sky at night.
2. Write a description of what is seen.
3. Answer the questions:
    a. Is the sky lighted up?
    b. Why are the planets visible?
    c. Why are the stars visible?
4. Share these experiences with the group.

Concept #5 - Artificial satellites are being used by man to further his study of earth and space.

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Experience A: Viewing a report on the importance of satellite observations to the study of earth and space

Materials needed:

film, "Earth Satellites: Explorers of Outer Space"
film, "Satellites: Stepping Stones to Space"
motion picture projector, 16 mm

What to do:

1. View the films: "Earth Satellites: Explorers of Outer Space," which contains some footage on the use of satellites, and/or, "Satellites: Stepping Stones to Space," which explains why satellites are important to man.

2. Make a list of the new discoveries which these films indicate are the result of satellite observations.

Experience B: Charting a history of advances in science resulting from artificial satellite studies

Materials needed:

reference materials (textbooks, encyclopedias)
pencil
paper

What to do:

1. Make a chart listing all of the satellites that have been launched.

2. Indicate the purpose of each satellite and the special scientific equipment included. Include the weight and size of the rocket and diagrams showing the orbital paths which may make this chart more useful.

3. Indicate the discoveries made and the new projects resulting from each satellite.

4. Keep the chart up-to-date as each new satellite is launched.

Concept #6 - Anything within the solar system is known as being in interplanetary space.

Note: See the introduction for a listing of some activities to review the distance relationships in the universe.

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Experience A: Learning the relationship of the different terms used to define parts of "space"

Materials needed:

paper
pencil, pen or crayons
reference materials

What to do:

1. Read several current articles on space travel which include information on a system of naming different related parts of space.
2. List the terms used and their definitions.
3. Make a chart relating the different names for the different parts of space as you have collected them from different systems of naming.

Experience B: Discovering the vastness of space by calculations of scaled relationships

Materials needed:

paper
pencils, colored
city map
chart, "Some Astronomical Facts and Approximations for Teaching," Appendix A

What to do:

1. Use the chart in Appendix A to find the diameter of the earth and sun.

2. Find the distance from the earth to the sun. Write the number out in full and label it "astronomical unit" (A.U.).

3. Calculate the distance light would travel in one minute, using the fact that light travels 186,000 miles in one second (186,000 x 60).

4. Calculate the distance light travels:

   a. In one hour (186,000 x 60 x 60)

   b. In one day (186,000 x 60 x 60 x 24)

   c. In one year (186,000 x 60 x 60 x 24 x 365½)

   Label the distance light travels in one year as a light year and round the number off to the nearest trillion.

5. Calculate the distance in miles from the earth to the nearest star which is 4-1/3 light years away (about 26 trillion miles).

6. Draw models of parts of our galaxy, using a dot, assumed to be 1/32" in diameter, to represent the diameter of the sun. Use the same scale and calculate the distance needed to represent the distance to the nearest star in inches, (1/32 x 26,000,000,000,000 ÷ 864,000), feet or miles (about 941,000 inches or 78,500 feet or nearly 15 miles).

Experience B (continued):

7. Use the scale on the city map and use a colored pencil to make a circle with its center at your school and with a radius the number of miles calculated in step 6.

For high achievers:

1. Calculate the diameter of the solar system in:

   ________ miles (2 x 3,679,000,000)

   ________ astronomical units (80 A.U.)

   ________ light years (0.001 L.Y.)

2. If it is 4-1/3 light years from the earth to the nearest star, Alpha Centauri, calculate the distance in astronomical units.

3. If we wish to draw a diagram of the solar system and its nearest star, Alpha Centauri,

   a. What scale should we use?

   b. If we draw our solar system as 1/2" in diameter, how far away would we place Alpha Centauri on the diagram? (4-1/3 x 1/2 ÷ .001)

Concept #7 - Man is beginning to travel up or "out" into interplanetary space.

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Experience 1: Keeping a file which traces the steps made towards interplanetary space travel

Materials needed:

periodicals (newspapers, magazines)
scissors

What to do:

1. Make a collection of pictures, articles and newspaper clippings about new advances in manned space vehicles and equipment.
2. Keep a chronological file of these clippings. Be sure to keep it up-to-date.

Experience B: Reporting about one phase of the progress made towards the interplanetary space travel

Materials needed:

clippings (from experience A)
paper
pencil

What to do:

1. Select interesting pictures and articles about one phase of the steps taken towards interplanetary space travel.

2. Make a bulletin board display from the clippings selected in step 1.

3. Prepare a brief written or oral summary to call attention to important facts illustrated in the display and to summarize its content.

Concept #8 - Anything beyond the solar system is known as being in outer space.

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Experience A: Discovering the common misunderstandings about the universe and outer space

Materials needed:

pencil
paper

What to do:

1. Have each member of the class draw a sketch containing:
   - a. The earth
   - b. The solar system
   - c. The milky way galaxy
   - d. The universe
2. Analyze each sketch with the class for the truths and fallacies of each drawing.
3. Label outer space in each drawing.

Concept #9 - There is a very slight amount of air in outer space.

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Experience A: Finding that the amount of air is very small in outer space

Materials needed:

reference materials (textbooks, encyclopedias)
pencil
paper

What to do:

1. Search the reference materials to find data explaining how far from the surface of the earth a rocket goes to be above:
    a. 50% of the atmosphere (about 4.7 miles or 25,000 ft.)
    b. 90% of the atmosphere (about 11.75 miles or 62,000 ft.)
    c. 99% of the atmosphere (about 18.9 miles or 100,000 ft.)
2. Find information regarding the amount of air in outer space.
3. Prepare a report for the class about this information

Concept #10 - Nearness and farness in comparing bodies in space is relative.

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Experience A: Calculating the relationship of distances in the solar system

Materials needed:

pencil
paper
chart, "Some Astronomical Facts and Approximations for Teaching," Appendix A

What to do:

1. Look up the distance of the earth from the moon and the sun.
2. Round off these numbers so there is only one integer other than zero.
3. Write a fraction with the distance to the moon as the numerator and the distance to the sun as the denominator.
4. Reduce the fraction to lowest terms to find what fraction of the distance to the sun is the distance to the moon.
5. Use the distance to the next nearest star equal to 26 trillion miles and find the fractional part of the distance to the nearest star which is the distance to the sun.
6. Discuss the question: "Is the sun near or far from the earth?"
7. Calculate the distance from the earth to the other planets as fractional (inferior planets) or mixed number multiples (superior planets) of the distance from the earth to the sun. Use the same procedure as used in steps 1 - 5.
8. Formulate a definition of "near" and "far" usable in the study of the universe and space travel.

Experience B: Discovering the difficulty of measuring distances to stars and the use of "magnitudes"

Materials needed:

chart, "Twenty Stars of the First Magnitude," Appendix B
flashlights, 2, different strength
sheet of paper, 8" x 11"
pin
reference materials, (textbooks, encyclopedias)

What to do:

1. Make a pin hole in the center of the piece of paper.
2. Go outside.
3. Have a child carry the flashlights away from the class to the other end of the block.
4. Have the child turn on the dimmer flashlight.
5. Hold the paper between the flashlight about 18" from the eye. Observe whether the flashlight is visible through the pin hole.
6. Have the child walk closer, if the light is not visible. Have him walk farther away, if the light can be seen. Turn off the flashlight.
7. Measure the farthest distance to the flashlight at which the light is visible.
8. Repeat steps 2 through 6 with the brighter flashlight.
9. Compare the distances. Explain why the distances are not equal.
10. Repeat steps 2 - 8 on a dark night guessing the distance before measuring.
11. Stand at one distance. Turn both flashlights on. Note whether it is possible to distinguish a difference in their brightness.
12. Compare the results for day and night.

Experience B (continued):

13. Answer the questions:

    a. Can a brighter light be seen from farther away?

    b. Is it easy to measure the distance?

    c. Would it be easy to measure distances of billions of miles?

    d. Are lights brighter when they are closer?

    e. Would comparing the brightness of stars give some information about their nearness or farness?

    f. Would the brightness (magnitude) of a star depend on their distance and the amount of light they produce?

14. Refer to the chart, "Twenty Stars of the First Magnitude" in Appendix B.

15. Consult reference materials to find examples of the use of the "magnitudes" to describe stars.

Concept #11 - Great distances in the universe are measured in terms of light years, the distance which light travels in one year.

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Experience A: Review experience B for Concept #6, page 21 and experience B for Concept #10, page 29

Concept #12 - Units of time in space may be measured differently from the units of time on earth.

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Experience A: Studying the meaning of time zones

Materials needed:

pencils
paper
globe, terrestrial
reference materials (textbooks, encyclopedias)

What to do:

1. Consult reference materials to discover the history of time zones.

2. Find answers to the following questions:

   a. How did American pioneers tell time?

   b. Would the times called "sun up", "noon" and "sun down" be the same 50 or 100 miles apart?

   c. When did it become important to know what time it is somewhere else?

   d. How many degrees of longitude are included in one time zone?

   e. Where is zero longitude?

3. Look at the globe. Find zero longitude.

4. Find the line representing 15° east longitude and the other line representing 15° west longitude.

5. Count the number of time zones on the earth.

6. Explain the need for an international date line at 180° (east or west) longitude.

7. Imagine an airplane is flying toward the 180th meridian from east to west at 9:00 A.M. Explain what time it is after it has crossed the international date line. Explain what time it is if the airplane flies from west to east.

Experience A (continued):

8. Discuss the disadvantages of using this method of telling time during space travel. (It may be interesting to look up "Z" time or Greenwich time as used by the Air Force.)

Experience B: Discovering the importance of standard time

Materials needed:

watches
cloth, large enough to cover clock

What to do:

1. Explain to the principal and the parents the purpose of this experience to prepare them for the difficulties to be encountered.

2. Have each child close their eyes and set their watches. Caution them not to turn them too far from the actual time.

3. Cover the clock with the cloth.

4. Carry on the usual school work for one day having each child use the time indicated by his own watch to determine the time for each activity.

5. Discuss these questions:

   a. Is it difficult to conduct a class when class members come at different times?

   b. Did some of the children want to synchronize their watches?

6. Use the results to explain the importance of one standard unit of time for space travel. Suggest problems which could arise if a standard unit of time is not used.

Experience C: Suggesting units of time for other planets

Materials needed:

chart, "Some Astronomical Facts and Approximations for Teaching," Appendix A
pencil
paper

What to do:

1. Refer to the chart, "Some Astronomical Facts and Approximations for Teaching" to find the number of earth days required for Mercury to revolve around the sun.

2. Find the number of earth days required by Mercury to rotate once on its axis.

3. Calculate the number of Mercury days in one Mercury year by dividing the number of days found in step 1 by the number of days in step 2.

4. Have a child representing Mercury walk counter-clock around a second child representing the sun during which "Mercury" turns (rotates) around once counter-clockwise. (It should become apparent the same side of the first child is always towards the second child.)

5. Discuss the question, "Would there be night and day (periods of darkness and light) on Mercury?"

6. Calculate the number of earth hours in one Mercury day by multiplying the number of days found in step 2 by 24.

7. Suggest a new unit of time which would be more useful on Mercury.

8. Find the data for Mars and repeat the experience.

Experience D: Discovering that time is defined by regular occurences on the earth

Materials needed:

globe, terrestrial
flashlight

What to do:

1. Go to the gymnasium. Darken the room completely.
2. Have a child hold the flashlight pointing towards one side of the globe. Stand at one end of the gym as far from the class as possible.
3. Switch on the flashlight. Have a second child move the globe from west to east.
4. Note whether it is easy to see and identify the continents from across the length of the gym.
5. Return to the classroom.
6. Imagine that you are orbiting the earth.
7. Answer the question: Would the sun "rise" and "set" once every 24 hours?
8. Discuss whether it would always be possible to observe from great distances in space when one 24 hour period has passed on earth.
9. Imagine you are going out into space. Discuss whether it would always be possible to tell when a year had passed on earth if you were not close enough to observe the change in seasons.
10. Discuss methods of telling time which do not depend on a knowledge of the movements of the earth. Suggest other units of time which could be used in place of a day and a year.
11. Discuss the problems which would arise because of the use of this new unit, such as, the difficulty of converting back to earth time.

Concept #13 - There are many problems which must be studied and solved before man can travel for extended periods of time in space.

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**Experience A:** Viewing an illustration of some problems of travel in interplanetary space

Materials needed:

film, "Man in Space"
motion picture projector, 16 mm
projection screen
reference materials (encyclopedias, periodicals, recent books)

What to do:

1. View the film, "Man in Space," which presents information on the problems which need solutions before man can go into interplanetary space.
2. List the problems suggested. Survey recent reference materials to learn of the progress which has been made towards the solution of the problems.
3. Find descriptions of new problems which have been identified and make a report about them to the class.

**Experience B:** Reviewing the problems which have already been solved in aerospace history

Materials needed:

pencil
paper

What to do:

1. Make a time line showing the history of aviation and astronautics from balloons to rockets taking man into space. Include in the history the following data for each flight:
    a. date
    b. altitude attained
    c. method of controlling temperature and pressures for pilot and passengers, such as, sealed vs. open cabin or gondola
    d. method of oxygen supply for pilot and passengers
    e. maximum speeds attained
2. Make a list of problems related to rocketry and space travels for which no complete solution has been found, such as, danger from Van Allen radiation.

Experience C: Keeping a record of advances in space technology

Materials needed:

scrap book
paste
scissors
periodicals
colored sticker

What to do:

1. Look for clippings related to advances in space technology.

2. Sort the clippings and group them according to the subject.

3. Make a section of the scrap book for each subject, such as, selection and training of astronauts; space medicine; rocket fuels; guidance and control systems.

4. Continue to add to the scrap book.

5. Mark the problems for which solutions have been found with a colored sticker. Make a new section for each new problem which arises.

6. Use the scrap book as a reference material.

7. Give periodic reports to the class which summarize the advances made towards finding solutions for the problems of space travel.

**Experience D:** Becoming aware of the "hardware" in the environment for a man during space travel

Materials needed:

film, "Man in Space"
film, "Screen News Digest No. 8"
motion picture projector, 16 mm
projection screen
scraps of wood, cloth, elastic, wire
paint
water
reference materials (encyclopedias, periodicals, recent books)
aluminum foil
doll, about 24" long
newspaper
wheat paste
barrel or circular cardboard carton (used for shipping dry chemicals)

What to do:

1. View either of the films, keeping careful notes of the size, shape and location of the "hardware" (equipment) within a space capsule.
2. Use the inside of the barrel to represent the inside of the space capsule.
3. Use paper mache' forms and pieces of scrap wood made to scale to represent the different objects. Devise ways to represent the food containers, the astronaut's couch, the capsule's controls and other pieces of equipment observed in the films.
4. Use pieces of cloth, elastic and aluminum foil to make clothing for the doll representing the astronaut.
5. Secure all the hardware and the doll in the barrel. View the film again to check the size, shape and location of each object.
6. Consult reference materials to check the arrangement of the parts of the capsule.
7. Roll the barrel over and over to discover whether any of the parts are loose. Explain why loose parts would be inconvenient and dangerous during space travel.
8. Note that very little of the inside of the barrel is empty. (Save this model for later use.)

**Experience E:** Measuring the effect of surface characteristics on the temperature of an enclosure

Materials needed:

aluminum foil
thermometer, Fahrenheit
paper
pencil

What to do:

1. Keep the windows closed. Turn off the thermostat.
2. Measure and record the temperature in the classroom and outside the classroom window once every hour throughout one school day.
3. Cover the windows with aluminum foil on a second day.
4. Measure and record the temperature in the classroom and outside the classroom window every hour during the second day.
5. Compute the differences between the inside and outside temperature for each pair of readings.
6. Repeat the experience several times to decrease the effect of daily weather variations.
7. Prepare graphs of the differences in temperature against the time for each day.
8. Compare the results. Draw conclusions concerning the probable effect of shiny metallic surfaces on the temperature inside of a space capsule. (If the windows are not north windows the results are more dramatic.)

**Experience F:** Becoming aware of the problems related to preparing for a trip to the moon

Materials needed:

reference materials (encyclopedias,
  periodicals, recent books)
chart, "Some Astronomical Facts and Approximations
  for Teaching," Appendix A
globe, terrestrial

What to do:

1. Consult references to find the distance between the earth and the moon.

2. Rotate the globe and observe which direction the rocket should be shot to take advantage of the earth's speed of rotation.

3. Consult references to find the time which is needed to travel to the moon.

4. Have one child representing the moon walk around another child representing the earth. Have a third child move a model of a space vehicle from the earth to the moon. Represent the trip from the moon to the earth in the same way.

5. Consult reference materials to find what preparations are necessary to make an astronaut ready for blast off.

6. Consult reference materials to find what preparations are necessary to make the rocket and capsule ready for blast off. Discover:

   a. How many pounds of food is needed for each astronaut.

   b. How many pounds of water is needed for each astronaut.

   c. How many pounds of oxygen is needed for each astronaut.

   d. How many pounds of fuel is needed.

   e. How much time is needed to put fuel in the rocket.

   f. How many "g's" the astronaut feels.

7. List all the steps needed to prepare for a space trip. Explain why each step is necessary.

Experience G: Studying the effects of too much or too little of a substance in the diet

Materials needed:

reference materials (encyclopedias, periodicals)
pencil
paper

What to do:

1. Consult reference materials concerning experiments conducted to determine how much salt water a man can drink before being poisoned.
2. Consult references to learn why blocks of salt are put out for animals. Find an explanation for the need to supply salt to animals.
3. Read references to find information relating to the need for vitamins. Find descriptions of the results of too little or too much of any one vitamin.
4. Assume that specially prepared foods are needed for space travel. Explain the importance of controlled amounts of each substance.

Experience H: Taking a hypothetical trip to the moon (Apollo Project)

Materials needed:

scale model of an Apollo space capsule

What to do:

1. Act out a trip to the moon. (Use the scale model of an Apollo space capsule.)
2. Simulate preparation of the astronaut and of the space vehicle. (See experience D, Concept #13, for suggestions.)
3. Simulate the count down and blast off. Act out the manipulation of control and data collecting instruments on the trip to and from the moon.
4. Conclude whether the model space capsule would supply the needs for a controlled environment for space travel.

- Concept #14:- There is a great need for trained people to study the problems of space travel.

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Experience A: Learning about the trained personnel required for research in problems of space travel

Materials needed:

reference materials, (textbooks, encyclopedias)
pencil
paper
book, Who's Who in Biological Science, (Use at Mpls. Public Library)
book, Who's Who in Physical Science, (Use at Mpls. Public Library)
book, Who's Who in America, (Use at Mpls. Public Library)

What to do:

1. Look in current reference materials to find the answer to the questions:
    a. What are the most difficult unsolved problems about space travel known today?
    b. Who would know the most about each of these problems?
2. Consult Who's Who to find what education and professional background each man has.
3. Discuss the question: Is much training required by scientists who work in space research?
4. Explain why there is a need for trained people to study the problems of space travel.

Concept #15 - As more is learned about space travel, other factors may be found which may limit man's existence in space.

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Experience A: Becoming aware of some of the questions which have to be answered before space travel becomes safe

Materials needed:

reference materials (textbooks, encyclopedias, periodicals)

What to do:

1. Consult reference materials to learn about some problems relating to man's safety; i.e.,
   a. How can a man be protected from the dangers of the Van Allen Belts of radiation?
   b. Are there unknown radiations beyond our solar system which would injure a man?
   c. Are there bacteria and diseases on other astronomical bodies which would be dangerous to a man?
2. Prepare a report for the class summarizing the questions and the prepared plans for finding the answers.

Concept #16 - New projects related to space travel are continually being developed and evaluated in order to expand upon existing knowledge.

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Experience A: Learning about the space travel projects planned for the future

Materials needed:

reference materials (textbooks, encyclopedias, periodicals)
pencil
paper

What to do:

1. Consult reference materials to find the name and purposes of each project in the United States Space Program; e.g., Project Gemini, Project Apollo.
2. Read about each project to discover whether each project is independent or whether it is related to the other projects.
3. Prepare an oral report for the class to summarize the information.

Experience B: Reviewing a problem in space travel which has been solved

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials describing Astronaut Grisson's flight.
2. Explain why the loss of the capsule was unfortunate.
3. Find more recent articles describing the way that this problem was solved.
4. Prepare a report for the class summarizing the information.

**Experience C:** Investigating a problem in communications with a hot capsule

Materials needed:

electroscope
liquid petroleum burner
match
rubber rod
cat fur, piece

What to do:

1. Rub a rubber rod vigorously with a piece of cat fur.
2. Touch the rod to the electroscope to cause the metal leaves to move apart.
3. Observe how much time elapses before the electroscope loses its charge.
4. Repeat the charging and discharge time measurement at least twice and average the times.
5. Energize the electroscope as before. Light the burner and place the electroscope near the flame.
6. Record the time which elapses before the electroscope loses its charge.
7. Repeat the measurement at least once and find the average.
8. Compare the results. (Heat ionizes the air which discharges the electroscope.)
9. Relate the observations to the problem of the communications black out with the hot space capsule during Astronaut Carpenter's flight.
10. Suggest some possible solutions for this problem.

Concept #17 - Results from one experiment in space research lead to the formulation of many other problems for study.

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**Experience A:** Reviewing the progress made on a problem growing out of an earlier experiment

Materials needed:

reference materials (periodicals, textbooks, encyclopedias)

What to do:

1. Read descriptions of the food eaten by Astronaut Glenn during his flight.
2. Consult recent articles describing the food eaten during Astronaut Carpenter's flight and Astronaut Schirra's flight.
3. Compare the kinds of food and note the changes made.
4. Suggest some further changes that could be made in the packaging and kinds of food.

**Experience B:** Discovering research can both answer questions and raise new questions

Materials needed:

reference materials (periodicals, textbooks, encyclopedias)
pencil
paper

What to do:

1. Read reference materials to find out as much as possible about a specific space flight.
2. Make a list of all the things which were predicted by scientists in planning the flight and found out by this flight to be true.
3. Make a list of the new questions and problems raised by this flight.
4. Make an oral summary of this information for the class.

Concept #18 - Problems in the building of space travel devices require the development of many materials.

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**Experience A:** Discovering different materials withstand different amounts of stress before they break

Materials needed:

wire, copper #18
Wire, iron #18

What to do:

1. Grasp the copper wire firmly. Bend it back and forth in one place counting the number of times it bends before it breaks.

2. Grasp the iron wire. Bend it back and forth in one place counting the number of times it bends before it breaks.

3. Summarize the observations. Explain why the two pieces of wire did not break with the same number of bends.

4. Use the results of the experience to formulate an explanation of the requirements for the strength of materials used in space vehicles.

**Experience B:** Discovering an object may be made of different materials to obtain a difference in weight

Materials needed:

frying pan, cast iron, 10" diameter
frying pan, stainless steel, 10" diameter
bathroom scales
reference materials (periodicals, textbooks, encyclopedias)

What to do:

1. Weigh a 10 inch cast iron frying pan.
2. Weigh a stainless steel frying pan which resembles the cast iron pan as closely as possible.
3. Compare the weights.
4. Discuss the importance of light weight materials in the construction of a space vehicle.
5. Consult references to find what materials are used to make a rocket and space capsule.

   (Rockets are made of extremely thin sheets of stainless steel to obtain a resilient material which is lightweight.)

Experience C: Illustrating the operation of a heat shield on a descending space capsule

Materials needed:

| | |
|---|---|
| ice cube | match |
| aluminum foil | rectangular iron support |
| asbestos, sheets | ring clamp |
| liquid petroleum burner | refrigerator |

What to do:

1. Cut 10 or more 4" x 4" pieces of aluminum foil. Cool them in the refrigerator.
2. Cut 10 or more 4" x 4" squares of asbestos. Cool them in the refrigerator.
3. Lay a sheet of aluminum foil over the ring clamp. Pile asbestos and aluminum squares alternately upon the first square of aluminum until half are used up.
4. Place the ice cube in the center of the top asbestos square and press another asbestos square down over it.
5. Pile the remaining aluminum and asbestos squares alternately over the ice cube.
6. Push the laminated material around the ice cube to close off the circulation of air around the ice cube.
7. Light the burner and heat the bottom piece of aluminum foil 10 minutes.
8. Open the package and observe the amount of melting.
9. Repeat the experiment cooling the aluminum and asbestos before each trial.
10. Compare the observations to the operations of the heat shield of a space capsule.

    (An ice cube embedded in the center of a thick pad of rock wool does not melt rapidly either. However, laminated aluminum and asbestos more closely simulate the structure of the heat shield on a space capsule.)

Concept #19 - Objects close to an astronomical body in space are attracted to that body.

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Experience A: Studying the suggestions made to slow space vehicles approaching the moon

Materials needed:

reference materials (periodicals, encyclopedias, textbooks)
pencil
paper

What to do:

1. Consult reference materials which explain the space projects to land men and equipment on the moon, such as Project Gemini and Project Apollo.
2. Find an explanation of the plan to use retrorockets to slow the space vehicle as it approaches the moon's surface.
3. Look for information concerning shock absorbing devices which are being developed to "break the fall" of the space vehicle as it strikes the surface of the moon.
4. Prepare a report for the class which answers these questions:
    - a. Why would a space vehicle approaching the moon fall rapidly?
    - b. What methods are proposed to slow the fall and decrease the force of impact?
    - c. Would similar problems have to be solved to make possible a landing on any astronomical body?

Experience B: Relating the number of revolutions to the distance from the center of revolution

Materials needed:

ball, sponge rubber, 1" diameter
screw, round headed, ½" long
fish line, 5' long
scissors
clock

What to do:

1. Tie one end of the fish line securely to the screw. Trim off any excess string at the knot.
2. Twist the screw into the ball as far as possible.
3. Grasp the fish line 1' from the ball. Hold the remainder of the line out of the way.
4. Twirl the ball in a vertical circle as slowly as possible but fast enough to keep it moving along a circular path.
5. Count the number of complete revolutions in one minute.
6. Grasp the fish line 2' from the ball. Twirl the ball as slowly as possible.
7. Count the number of circles in one minute.
8. Repeat grasping the line 3' and 4' from the ball.
9. Compare the number of revolutions in one minute to the radius of revolution in each trial.
10. Form a conclusion from the comparisons.
11. Explain what this has to do with orbiting of satellites.

Experience C: Observing the relation between the weight lifted and the speed of revolution

Materials needed:

pencil, piece 1" long
paper clip
washers, $\frac{1}{2}$" inside diameter, 8
screw round headed, $\frac{1}{4}$"
glass tubing, 3" long
ball, hard rubber, about 1" diameter
string, 3' long
clock, with second hand
glue

What to do:

1. Knot one end of the string around the screw. Coat the screw with glue and twist it into the ball.

2. Put the other end of the string through the glass tubing.

3. Knot the piece of pencil on the free end of the string. Turn the piece of glass tubing one half turn so the pencil is on the lower side and the ball is above the tubing. Slip a washer over the pencil, pushing it far enough up the string to allow the pencil to be turned perpendicular to the string, preventing the release of the washer. Drop the washer down the string until it rests on the wood.

4. Place a paper clip on the string 6" above the weight (washer).

5. Swing the ball, overhead in a horizontal circle, fast enough to lift the weight until the paper clip is about 1" below the glass tubing.

6. Count the number of revolutions made by the ball in one minute.

7. Repeat the measurement with 2, 5 and 8 washers for the weight.

8. Make a graph of the number of revolutions and the number of washers.

9. Compare the results and draw some conclusions regarding the relationship between the weight lifted and the speed of revolution.

Concept #20 - In outer space, the pull of the earth would be very slight.

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**Experience A:** Simulating the effect of varying forces of attraction on a mass

Note: In this experience electro-magnetic attraction is used to simulate gravitational attraction. Be sure the two forces do not become confused in the students' minds.

Materials needed:

string, 8" long, 2 lengths
storage battery, 6 volt
clips, alligator, 12
spring, from screen door
electromagnet
wire, copper, insulated, 2' long approximately, 6
sandpaper
nails, finishing, 2 pennyweight, 6
board, 3/4" x 3' x 3' long, plywood
knife, switch
bearing, steel ball
book

What to do:

1. Nail one end of the screen door spring to the board near one corner.
2. Remove the paint from the top of the spring along the entire length by rubbing with sandpaper.
3. Stretch the spring along the side of the board and nail the loose end to the opposite side of the board.
4. Pound a nail part way into the top of each terminal on the battery.
5. Place the electromagnet midway along the side of the board across from the door spring. Fasten it securely in place by pounding a nail into the board on either end of the electromagnet and winding a string around the nail and the electromagnet.

Experience A (continued):

6. Attach an alligator clip to each end of all 6 copper wires.

7. Clamp one alligator clip on one wire onto the nail in one terminal of the battery. Clamp the other alligator clip on this first wire to one side of the switch. Open the switch.

8. Clamp the alligator clips on a second wire, one to the other side of the switch and second to one end of the door spring where the insulation has been removed.

9. Clamp one end of the third wire near the same end of the door spring. Lead the other end under the board and around to one end of the wire on the electromagnet.

10. Connect the fourth wire with one end gripping the free end of the wire forming the electromagnet and the other grasping the nail in the other battery terminal.

11. Prop the board on a book so that the electromagnet is half way up on the incline.

12. Roll the ball bearing down the center of the board, noting the path of the ball bearing. Mark the place from which the ball bearing is released with pencil.

13. Close the switch and note the path of the ball bearing as it rolls down the incline this time.

14. Open the switch. Move the alligator clip further along the door spring.

15. Roll the ball bearing down the board again. Observe its path.

16. Repeat the experience, moving the alligator clip further and further away from the end of the spring where the other wire is joined.

17. Summarize the observations. Relate the results to the effect of the different amounts of gravitational attraction of different astronomical bodies on an object. (Moving the alligator clips apart increases the resistance of the circuit to the flow of electricity. When less electricity flows through an electromagnet, the magnetic field is weaker. Decreased magnetic attraction simulates decreased gravitational attraction.)

**Experience B:** Observing the effect of distance on the gravity influencing an object

Note: In this experience electro-magnetic attraction is used to simulate gravitational attraction. Be sure the two forces do not become confused in the students' minds.

Materials needed:

string, 8" long, 2 lengths
storage battery, 6 volt
clips, alligator, 12
spring, from screen door
electromagnet
wire, copper, insulated, 2' long approximately, 6
sandpaper
nails, finishing, 2 pennyweight, 6
board, 3/4" x 3' x 3' long, plywood
knife, switch
bearing, steel ball
book

What to do:

1. Nail one end of the door spring to the board near one corner.
2. Remove the paint from the top of the spring along the entire length by rubbing with sandpaper.
3. Stretch the spring along the side of the board and nail the loose end to the opposite side of the board.
4. Pound a nail part way into the top of each terminal on the battery.
5. Place the electromagnet midway along the side of the board across from the door spring. Fasten it securely in place by pounding a nail into the board on either end of the electromagnet and winding a string around the nail and the electromagnet.
6. Attach an alligator clip to each end of all 6 copper wires.
7. Clamp one alligator clip on one wire onto the nail in one terminal of the battery. Clamp the other alligator clip on this first wire to one side of the switch. Open the switch.

Experience B (continued):

8. Clamp the alligator clips on a second wire, one to the other side of the switch and the second to one end of the door spring where the insulation has been removed.

9. Clamp one end of the third wire near the opposite end of the door spring. Lead the other end under the board and around to one end of the wire on the electromagnet. (It may be necessary to decrease the resistance to obtain a stronger magnetic field.)

10. Connect the fourth wire with one end gripping the free end of the wire forming the electromagnet and the other grasping the nail in the other battery terminal.

11. Close the switch. Roll the ball bearing down the board so it passes close to the electromagnet. Observe the path the ball bearing follows.

12. Repeat the experiment several times starting the ball bearing further across the board away from the electromagnet. Observe the path each time.

13. Summarize the observations. Relate the results to the effect of greater distance on the gravitational attraction between the object and the earth.

(Note: This experience depends on the fact that the mathematical relationship of the distance between objects and the effective gravitational and magnetic attraction is identical.)

Experience C: Showing the decrease in weight resulting from increased distance from the earth

Materials needed:

chart, Appendix C
pencil
paper
paper, graph

What to do:

1. Assume that a 100 pound boy standing on the surface of the earth is 4,000 miles from the center of the earth's gravity.

2. Secure data for the weight of the boy at greater distances from the earth. (Note: Assume no other astronomical bodies influence the weight of the boy; that is, assume the boy moves in a direction away from the sun and the other planets.)

3. Graph the weight against the distance from the center of the earth. Use increases of 1,000 miles for 4,000 to 10,000 miles; i.e., use distances of 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 and 10,000 miles.

4. Make a second graph of the weight of the boy against distance using an increase of 10,000 miles for the boy's weight up to 50,000 miles, i.e., use distances of 10,000, 20,000, 30,000, 40,000, and 50,000 miles.

5. Assume that the distance of 3,600,000,000 miles is nearby "outer space."

6. Summarize the results and draw a conclusion explaining the effect of the earth's gravity on an object in outer space.

Concept #21 - Many natural phenomena result from the pull of the earth; e.g., weight, water running downhill.

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Experience A: Experiencing fatigue caused by gravity

What to do:

1. Hold your arms straight out from your sides.
2. Observe whether your arms feel heavy.
3. Note whether your arms seem to get heavier.
4. Use a clock with a second hand to measure the length of time you can keep your arms straight out.
5. Explain why you have become tired.

Experience B: Observing that objects roll downhill

Materials needed:

mail tube or other cylindrical object
board, shelf from bookcase
roller skate, or other wheeled device
books

What to do:

1. Prop up one end of the board on a book.

2. Roll a mail tube down the sloping board.

3. Increase the amount of slope of the board by placing a second book on the first book under the board. Roll the mail tube down again.

4. Try a roller skate or any other wheeled device.

5. Develop an understanding that gravity is force acting indirectly on the objects moving down an inclined plane.

6. Identify the force which causes rocks to roll downhill.

Experience C: Tracing the direction of flow of moving water

Materials needed:

physical features map of the United States
physical features map of Minnesota
plaster of Paris
sand
water
stick

What to do:

1. Obtain a physical features map of the United States. Point out that all rivers run from higher to lower ground.

2. Trace the flow of the Mississippi River, noting changes in elevation.

3. Repeat tracing the flow of Columbia River, Red River of the north, and other rivers.

4. Go out into the school yeard. Find a place where the water drainage divides in two directions. (A street is raised in the middle to provide a water drainage "divide".)

5. Define the terms "divide" and "continental divide" in terms of the observations.

6. Form a plaster of Paris and sand model contour map to show the physical features of the school yeard. Use a stick to stir the mixture and to shape the model. Allow the model to harden.

7. Sprinkle water over the model and observe the directions that the water flows.

8. Study a physical features map of Minnesota. Identify the two continental divides in the state.

Experience D: Discovering that the center of gravity moves downhill

Materials needed:

boards, 1" x 1" x 2', 2
book
paper cups, cone shaped, 2
string
tape, masking

What to do:

1. Place the two boards beside each other. Bind the two boards together at one end.
2. Separate the opposite ends so that the boards form a "V".
3. Place the separated ends of the boards on the book.
4. Place the lips of the two cups against one another. Tape them together.
5. Place the paper cups (double cone) on the boards.
6. Observe whether the cups roll down the inclined plane.
7. Explain the results.

Experience E: Discovering that easily moved objects shift to move the greatest amount of weight closest to the earth

Materials needed:

ping pong ball
wax, "Sealstix"
book
student desk

What to do:

1. Place a ping pong ball on a book which is resting flat on a desk.
2. Tip up one end of the book slightly and momentarily; and lower it again.
3. Observe what happened to the ball.
4. Replace the ball and raise another side of the book slightly.
5. Explain why the ball moves.
6. Repeat many times, tipping the book in different directions.
7. Predict which direction the ball will move if the book is tilted in a specific direction. Test the prediction.
8. Decide what determines the direction of the movement of the ball.
9. Punch a slight, permanent depression into the ball. Place a small piece of wax in the depression. Repeat the experiment.
10. Explain why the results are different.

**Experience F:** Observing how the center of gravity of an object always moves as close to the earth as possible

Materials needed:

potato, very small (cut a large potato into eighths)
fork, metal, 2
pencil, long
table
bottle, tall, small mouth, with cap

What to do:

1. Push the sharpened end of the pencil through the width of the potato. Allow the sharpened end of the pencil to extend about $1\frac{1}{2}$" beyond the potato.
2. Stick one of the forks with the handle curving downward into the potato beneath the place where the sharp end of the pencil comes out of the potato at an angle close to the horizontal. Note that the handle of the fork is pointed in the same direction as the pencil point.
3. Lay the side of the sharpened end of the pencil on the table with the fork extending below and beneath the table edge. Adjust the location of the fork if balance is not obtained.
4. Tap the long end of the pencil gently. Observe what happens.
5. Pull the pencil out of the potato until only the sharpened point extends beyond the potato.
6. Insert a second fork into the potato at the same angle as the first fork on the other side of the sharpened pencil point.
7. Balance the point of the pencil on the cap of the tall bottle. Adjust the forks to obtain balance.
8. Explain in terms of center of gravity why the potato does not fall to the floor.

**Experience G:** Discovering that some objects do not move towards the center of the earth unless work is done on them

Materials needed:

plaster of Paris
sand
water
marble
screen, window, about 6" x 18"
pencil
cardboard, 12" x 12"
hair pins, 6

What to do:

1. Roll the screen into a cone shape. Weave a hair pin through the screen at the top and the bottom of the cone to hold it in shape.
2. Rest the cone on the cardboard and draw a circle around the base.
3. Push both ends of the other 4 hair pins through the cardboard at places spaced along the circle drawn on the cardboard. Push each hair pin through the screen and twist the ends together.
4. Coat the screen and cardboard with a mixture of plaster of Paris and sand to make a model of a hill. Form a small depression at the top of the hill. Allow the model to harden.
5. Place a marble in the depression on the top of the hill.
6. Note whether the marble rolls downhill.
7. Suggest a way to cause the marble to roll downhill. Predict which side it will roll down. Note that every suggestion includes some way of doing work on the marble.
8. Test the prediction.
9. Explain the results.

**Experience H:** Observing that the rate of fall of two objects does not depend on the horizontal distance

Materials needed:

pennies, 2
table
ruler

What to do:

1. Place the two pennies near the edge of the table.

2. Push them off the table with a ruler which is moving parallel to the edge of the table. Observe whether both strike the floor at the same time. (It may be easier to determine whether they strike at the same time if the eyes are shut and the results determined by sound.)

3. Place the two pennies near the edge of the table about 6" apart.

4. Grasp one end of the ruler and hold it in place 3/8" from the edge of the table.

5. Swing the ruler in a wide arc, pushing the pennies off the table at the same time. Observe whether both pennies strike the floor at the same time.

6. Decide whether the horizontal distance the pennies travel makes any difference in the time required for them to fall a given distance.

**Experience I:** Learning that moving objects fall unless another force is stronger than the force of gravity

Materials needed:

string, 2½ feet long
ping pong ball
wax, "Sealstix"

What to do:

1. Attach a string to a ping pong ball with some wax.
2. Grasp the other end of the string. Swing the ball in an arc. Observe the the ball rises in an arc, stops, and swings downward in the same arc.
3. Note the ball moves downward, but is not pulled downward by the string.
4. Swing the ball in an arc again.
5. Move your hand quickly towards the ball as it rises near one end of the arc. Observe what happens to the ball.
6. Swing the ball in a gradually increasing arc but not in a complete circle. Note that after the string has gone above the position where the string is horizontal, the ball falls straight down if it is not swinging too rapidly.
7. Explain the observations.

## Concept #22 - Weight is an important factor when planning a rocket's escape from the earth's gravity.

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**Experience A:** Discovering there is a limit to the height an object can attain related to the amount of energy available

Materials needed:

string, about 10' long
crayon
yard stick
washers, 10
brick, heavy construction

What to do:

1. Knot the washers in one end of the string.
2. Lay the string on a flat surface. Use the yard stick to measure lengths on the string. Mark the string with a crayon every 6".
3. Hang the string from the ceiling by tieing it to some firmly mounted object.
4. Stand beside the string and reach up as high as possible, note the number of marks up to the tips of the fingers.
5. Jump up as high as possible and touch the string.
6. Calculate the height of the jump by counting the number of marks reached in the jump and subtracting the number of marks reached in step 4. (Greater accuracy can be obtained by estimating the fractional distance between marks reached during the jump.) Multiply the difference by 6".
7. Repeat steps 5 and 6. Calculate an average.
8. Explain why it is not possible to jump much higher.
9. Grasp the brick in one hand. Jump up as high as possible and touch the string.
10. Calculate the height of the jump in the same way as step 6.

Experience A (continued):

11. Explain why the height of the jump with the brick is different from the height of the jump without the brick.

12. Suggest ways of obtaining additional energy so that it may be possible to jump higher.

13. Explain why a heavy load requires more fuel for energy than a light weight load during launching a satellite into orbit.

**Experience B:** Calculating the ratio of the weight of the fuel required to the weight of the pay load put into orbit.

Materials needed:

reference materials (periodicals, encyclopedias)
paper
pencil

What to do:

1. Consult reference materials which provide data about the weight of rocket fuel and the weight of the satellite for many different satellites.
2. Make a chart containing this information. Include in the chart a fraction calculated from the data using the weight of the fuel as the numerator and the weight of the satellite as denominator.
3. Summarize the information and formulate a general statement about the importance of weight to the ease of escaping the earth's gravity.

Experience C: Discovering the importance of weight in designing devices for low level flying

Materials needed:

reference materials (recent periodicals, books)

What to do:

1. Read recent periodicals about new devices planned for use in low altitude flying; e.g., Army's air floating jeep, Marine's individual jet propulsion unit.
2. Explain how these devices operate. Explain how energy is used to work against gravity.
3. Discover whether heavier objects require more energy than lighter objects.
4. Prepare a report for the class using this information to illustrate the importance of weight in determining the amount of energy required for getting off the surface of the earth.

## Concept #23 - To get into interplanetary space a rocket must "push" harder than the earth pulls.

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Experience A: Discovering the effect of balanced forces in a tug-of-war

Materials needed:

rope, 6' long

What to do:

1. Go out onto the playground.
2. Form two teams of five children each for a tug-of-war
3. Have each team pull on different ends of the rope.
4. Note that when the two teams pull equally hard the center of the rope does not move.
5. Have another child join one team and note the direction that the center of the rope moves. Change the direction of movement by having the child join the other team.
6. Explain what happens when two forces are equal.

**Experience B:** Discovering the effect of balanced and unbalanced forces

Materials needed:

spring balances, 2

What to do:

1. Hook the two spring balances together.
2. Pull equally hard in opposite directions with both spring balances. Note that the balances do not move.
3. Pull harder with first one and then the other spring balance. Observe the direction the balances move.
4. Explain why the balances move.

## Experience C: Discovering why satellites remain in orbit

Materials needed:

single pulleys, 2
spring scale
weight, 1 oz.
nails, 2 pennyweight, 3
string, 5' long
washer, 7/16"
compasses
piece plywood, 2' x 2'
Dennison paper fastener, 1/2"
terrestrial globe
rectangular iron support
wax, "Sealstix"
ruler, rigid
scissors
chalk, soft

What to do:

1. Nail the two pulleys to opposite corners of the plywood.
2. Pound the third nail into the plywood at one of the other corners.
3. Thread the string through the washer. Knot the washer in the center of the string.
4. Thread one end of the string over each of the pulleys.
5. Loop the washer over the nail in the third corner.
6. Tie a loop in both ends of the string.
7. Prop the plywood up so that one pulley is down and the washer and other pulley are on the upper side of the board. Lean the board against a wall or support it with a rectangular iron support.
   Move it to the edge of the table so that the string from the lower pulley can hang over the edge.
8. Hang the 1 oz. weight from the loop at the lower side of the board. Slip the hook of the spring scale in the other loop and pull with a 1 oz. force.
9. Remove the washer from the nail. Insert a soft piece of chalk through the washer.
10. Note that the chalk is in the center of the washer. Hold the washer in place and make a dot on the board. Allow the washer to move slowly across the board. Make a dot in the center of the washer when it has stopped moving.

Experience C (continued):

11. Draw a line to connect the two dots to indicate the direction the washer moved. (The chalk may have made a line already).

12. Compare the direction the washer moved to the two directions in which it was pulled.

13. Change the direction of the plywood so that the other pulley is down. Repeat steps 8 to 12.

14. Explain why the washer does not move in either of the two directions it is being pulled.

15. Draw a circle 1" in diameter on the cardboard. Draw three pairs of parallel lines 1/2" apart and about 12" long.

16. Cut out the circle and the three pairs of lines. Cut a point in one end of each cardboard strip to make it into an arrow.

17. Join the blunt ends of the arrows and the center of the circle together with a paper fastener.

18. Use two arrows to show the direction of the pull (the 1 oz. weight and the 1 oz. force) and the third arrow to show the direction of movement of the circle (washer).

19. Use this model to show that the circle moves in a direction half way between the two pulls.

20. Hold the model near the globe so that one of the arrows points towards the center of the earth and that another is at 90° angles to the first arrow.

21. Show the direction that the circle would move with the third arrow.

22. Repeat steps 20 and 21 a large number of times at different places above the surface of the globe. Note the direction that the circle takes as it is moved around the globe.

23. Compare the movement of the circle around the globe to the orbiting of a satellite.

24. Identify the arrow representing the gravitational pull of the earth and the arrow representing the movement of the rocket towards space. Explain how forces keep a satellite "falling" around the earth.

Experience D: Observing the effect of two opposing forces

Materials needed:

wooden spool
ball, sponge rubber, 1" diameter
screw, round headed, 1/2" long
fish line, 4' long
scissors
weight, 1/2 lb.
clock, with second hand

What to do:

1. Tie one end of the fish line securely to the screw. Trim off any excess string at the knot.
2. Twist the screw into the ball as far as possible.
3. Thread the fish line through the spool. Tie the weight to the free end.
4. Grasp the spool. Twirl the ball overhead.
5. Count the number of circles the ball must make in one minute to hold the weight when a short length of line is between the ball and the spool. Count the number of circles in one minute which are required when the length is long.
6. Compare the results.
7. Explain the observations in terms of two forces -- gravity and angular momentum.
8. Explain how the experience illustrates that satellites close to the earth require less time for one revolution than those further away from the earth.

Concept #24 - The harder a rocket "pushes" away from the earth, the farther it can go before it begins to fall.

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Experience A: Relating the amount of effort exerted to the altitude obtained

Materials needed:

ball

What to do:

1. Throw a ball vertically into the air. Note how high it goes.
2. Throw the ball many more times varying the amount of effort used. Note how high it goes each time.
3. Compare the amount of effort used to the height the ball rose.
4. Summarize the observations. Explain how the results illustrate that the harder a rocket "pushes" the higher it rises before falling.

Experience B: Illustrating the relationship of the amount of energy to the distance traveled

Materials needed:

pencil
paper
Park's Satellite Rocket, Park Plastics, Linden, N. J.
water, cool, clear
tape measure
chalk

What to do:

1. Go out on the playground. Mark a chalk mark on the ground.

2. Fill the rocket about 1/2 full of water.

3. Stand on the mark. Pump the air into the rocket with one full stroke.

4. Fire the rocket horizontally. Measure the distance the rocket travels.

5. Repeat the experiment, using 2, 3 and 4 full strokes. Record the distance. Consult the directions to find whether it is possible to repeat using 6 and 8 strokes.

6. Graph the number of strokes against the distance.

7. Formulate a conclusion regarding the relationship between the effort used and the distance traveled.

Concept #25 - A rocket which "pushes" hard enough can go farther than the distance beyond which the earth can pull it back.

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Experience A: Observing the action of an object freed from centripetal force

Materials needed:

ball, sponge rubber, 1" diameter
screw, round headed, 1/2" long
fish line, 1' long
scissors

What to do:

1. Tie one end of the fish line securely to the screw. Trim off any excess string at the knot.
2. Twist the screw into the ball as far as possible.
3. Grasp the fish line at the end away from the ball.
4. Twirl the ball in a circle.
5. Let go of the line. Observe whether the ball continues in the circular path.
6. Repeat many times to determine whether there is any pattern to the direction in which the released ball travels.
7. Relate the results to the escape of a rocket from the earth's gravitational pull.

Experience B: Simulating the movement of an object beyond the earth's gravity

Materials needed:

weight, 1/2 lb.
thread

What to do:

1. Go outside on the playground. Stand away from the school building.

2. Tie a half pound weight to a piece of thread.

3. Swing it in a circle. Observe what happens when it swings rapidly enough to break the thread. Take care that no children can be struck by the weight either while swinging in a circle or after the thread has broken.

4. Relate this to the escape from the gravitational attraction of the earth of a rocket which has reached escape velocity. (It is important to remember the earth's gravitational pull does not stop suddenly. The gravitational pull decreases with an increase in distance.

Experience C: Reviewing the history of space probes beyond the earth's gravity

Materials needed:

reference materials
paper
pencil

What to do:

1. Consult reference materials to find data on the attempts to orbit the moon, sun, Venus and Mars.
2. Find information concerning:
   a. How far each space vehical traveled.
   b. Whether the space vehicle will return to the earth.
3. Prepare a report for the class about space vehicles which have gone so far the earth cannot pull them back.

Concept #26 - It is possible to place objects out into space by starting them with enough force and speed to escape the gravity of the earth.

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Experience A: Review Experience C from Concept #25

Experience B: Reviewing manned orbital flights which escaped the earth's gravity

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials concerning the orbital flights of Friendship 7, Aurora 7, and Sigma 7.

2. Find out whether these space capsules were "weightless" at any time. Prepare a report for the class explaining how weightlessness is a result of escape from the earth's gravity.

Concept #27 - In order for an object to escape the gravity of the earth, it must reach a greater speed than that required to orbit the earth.

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Experience A: Relating the launching speed to the kind of orbit or to escape from the earth's gravity

Materials needed:

reference materials (periodicals, encyclopedias)

What to do:

1. Consult reference materials to obtain data on orbiting satellites.
2. Make a chart of the launching and orbital speeds and the distance at apogee and perogee for each satellite.
3. Compare their speeds to the apogee distances. Note that the higher satellites do not need so much speed to go into orbit but require a greater launching speed to place them further from the earth.

Concept #28 - Gravity decreases as one leaves the earth, but increases as one approaches other astronomical bodies.

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Experience A: Viewing an illustration of a change of gravity resulting from a change in distance between objects

Materials needed:

film, "Gravity"
motion picture projector, 16 mm
projection screen

What to do:

1. View the film, "Gravity." See the annotation in the film bibliography.

2. Formulate an explanation of the effect distance has on the strength of gravitational attraction of astronomical bodies.

## Concept #29 - The moon "pulls" on things on the earth.

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**Experience A:** Finding pictures of tide differences which are the result of the moon's pull

Materials needed:

books, reference (geography, encyclopedias)

What to do:

1. Look in reference books to locate pairs of pictures showing the same place during high and low tides. (The Bay of Fundy has a 53½ feet tide difference.)
2. Read a description of the reason behind the twice daily occurance of high and low tides.
3. Consult the references further to find the answers to the questions:
   a. Does Lake Superior have tides?
   b. Are there tides in the earth's atmosphere?
4. Prepare a report for the class explaining the causes of tides.
5. Look for other examples of the effects of the moon's pull on the earth.

For high achievers:

1. Consult references to find an explanation of spring and neap tides.
2. Explain what other astronomical body or bodies exert a gravitational attraction on the earth.

Experience B: Explaining the action of water tides

Materials needed:

balloon
globe, terrestrial

What to do:

1. Have a child who has gone on vacation to the seashore describe the change in the location of the shore resulting from the tides in the ocean.
2. Blow up a balloon and knot the end.
3. Pull on part of the balloon and observe how the balloon changes shape.
4. Look at the globe. Imagine something is pulling on the water in the Pacific Ocean. Conclude what effect the pull would have.
5. Compare the rubber balloon pushing on the air in the balloon to the force of gravity pulling on the ocean's water.
6. Explain the causes of tides.

## Concept #30 - The gravitational pull on surface objects is greater on the earth than on the moon.

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### Experience A: Simulating an illustration of objects with different gravitational attraction

Note: This experience actually has nothing to do with gravitational attraction; gravitational attraction is simulated by magnetic attraction.

Materials needed:

magnets, bar, with different strengths, 2
ruler, non-magnetic
ball bearing, steel, small
thumb tacks, many

What to do:

1. Test the strength of each magnet by bringing each near a pile of thumb tacks. Record the strength of the magnets as the number of tacks it can lift.
2. Lay the ruler on a smooth, level surface.
3. Place one end of the stronger magnet even with the beginning of the ruler.
4. Lay the ball bearing beside the opposite end of the ruler and very slowly move it towards the magnet.
5. Read the distance of the ball bearing from the magnet when it begins to move toward the magnet due to magnetic attraction. Repeat the measurement and average the results.
6. Place the ball bearing near the magnet. Move it away from the magnet until it is no longer pulled to the magnet. Read and record the distance.
7. Repeat the measurement several times and average the results.
8. Average the distance found in steps 5 and 7.

Experience A (continued):

9. Replace the stronger magnet with the weaker magnet. Repeat steps 4 through 8, using the weaker magnet.

10. Compare the results for the two magnets. Note that the stronger magnet attracts the ball bearing more strongly than the weaker magnet.

11. Assume that gravitational attraction of different objects can be different as the force of the magnetic attraction in the above experience. Explain how this difference simulates the difference in the earth's and moon's gravitational attraction.

Experience B: Calculating the effect of the moon's gravity on an object

Materials needed:

pencil
paper
data "Some Astronomical Facts and Approximations for Teaching," Appendix A

What to do:

1. Assume the pull of the moon's gravity is equal to 0.16 of the pull of the earth's gravity.

2. Calculate how much a boy, weighing 100 pounds on earth, would weigh on the moon.

3. Discuss the problems and advantages which would be a result of this weight.

For over-achievers:

1. Refer to the data found in Appendix A and calculate the weight of a boy weighing 100 pounds on earth if he were on the surface of the other planets of the solar system.

2. Compute the weight of a 100 pound boy, measured on the surface of the earth, if he were able to exist on the "surface" of the sun. Assume the sun's gravity is 28 times the earth's gravity.

Experience C: Simulating the gravitational field between the earth and the moon

Note: Explain that for the purpose of the demonstration one magnet represents the earth and the other the moon, and that gravitational energy is represented by magnetic energy to simulate gravitational energy takes advantage of the identical mathematical relationship of distance to effective force.

Materials needed:

magnets, bar, different in strength, 2
thumb tacks or paper clips
graph paper
tape, masking
thread
ring clamp
rectangular iron support

What to do:

1. Test the strength of the magnets by seeing how many thumb tacks each magnet can pick up at one time.
2. Let the stronger magnet symbolize earth; the weaker the moon.
3. Take a strip of graph paper 3" long by 1" wide. Place the strip on the flat surface of a desk or table.
4. Tape the north end of one magnet to one end of the strip. Tape the south end of the second magnet to the other end of the same strip.
5. Suspend a thumb tack by a thread from a ring clamp attached to a rectangular support so that the suspended tack rests lightly on the strip between the two magnets.
6. Assume that the tack represents a space ship.
7. Move the tack back and forth along the strip until the place where the force of the two magnets equalize one another is located; i.e., the "ship" does not move as a result of attraction to either astronomical body.

Experience C (continued):

8. Move the tack toward the magnet representing the earth.
9. Note that the tack is attracted and would move to the "earth" if the thread would permit.
10. Move the tack in opposite direction toward the "moon" magnet.
11. Observe that as the "ship" is drawn to the "moon" magnet when the "moon's attraction" becomes stronger than that of the "earth."
12. Use the observations to explain why a space vehicle moving between the earth and the moon would be pulled to the earth or to the moon if its forward momentum becomes zero.

Concept #31 - The closer an object is to the moon, the greater is the mutual attraction.

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**Experience A:** Viewing instructional films which explain gravitational attraction

Materials needed:

film, "Gravity"
film, "Gravity - How It Affects Us"
motion picture projector, 16 mm
projection screen

What to do:

1. View the film, "Gravity."
2. Discuss the effect of the distance between objects on the gravitational attraction.
3. View the film, "Gravity - How It Affects Us."
4. Make a statement relating the distance between an object and an astronomical body to their mutual attraction.

Concept #32 - As two objects approach each other, the greater is the mutual attraction.

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Experience A: Repeat Experience C for Concept #30

Experience B:

For over-achievers:

Discovering the relationship of gravitational attraction to distance

Materials needed:

pencil
paper
books, 2
yardstick

What to do:

1. Place the books 1' apart on a table top.

2. Assume that the gravitational attraction between them is equal to a number (which is not known) divided by the product of the distance between them times the distance between them.

   $$\left(\text{gravitational attraction} = \frac{?}{d \times d}\right)$$

   Calculate this G.A. (gravitational attraction = $\frac{?}{1 \times 1}$;

   G.A. = ?)

3. Move the books so they are 2' apart. Calculate the gravitational attraction, G.A. = $\frac{?}{2 \times 2}$; G.A. = $\frac{1}{4}$?

4. Repeat step 3 using distances of 3', 4' and 5'.

5. Compare the answers. Formulate an explanation in your own words of the relationahip of gravitational attraction and distance. (The teacher may find the information in "A Mathematicl Comparison of the Earth's Natural and Proposed Artificial Satellites," Appendix D, interesting and helpful.)

## Concept #33 - Gravitational energy is opposed with parachutes.

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**Experience A:** Observing a difference in rate of fall due to a change in air resistance

Materials needed:

eraser, rubber
ladder, 5'
handkerchief
thread
stop watch, or clock with second hand
pencil
paper

What to do:

1. Climb to the top of the ladder. Raise the eraser as high as possible.
2. Drop the rubber eraser to the floor.
3. Note that the object falls rapidly because there is little air resistance.
4. Repeat several times, measuring the time required for the fall. Take care that the eraser is released from the same height each time.
5. Make a parachute by taking a large handkerchief and tying a thread to each corner of the handkerchief to represent the cords of a parachute. Tie the ends of thread together and attach the rubber eraser to the tied end of the "parachute cords."
6. Drop the parachute with eraser from the same height to the floor. Note that the eraser falls more slowly when there is more air resistance provided by the handkerchief.
7. Repeat several times, measuring the time required for the fall and find the average.
8. Draw conclusions based on the observations.

**Experience B:** Finding applications for the use of parachutes which oppose gravity

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find examples of the use of parachutes to work against gravity. (Do not include "drag parachutes" used by airplanes because their parachutes are not working against gravity.)

2. Make a chart which lists these uses and prepare an oral report of this information for the class. Be sure to explain the uses of parachutes in space travel.

Concept #34 - When approaching the earth, rockets and/or parachutes must be used to work against the earth's gravity to slow down the vehicle and thus prevent destructive impact.

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Experience A: Discovering what methods are used to slow the descent of a space capsule

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials describing the three orbital flights of the astronauts.
2. Find descriptions of the methods used to slow the descent of the vehicle for re-entry.
3. Find what methods are used to slow the descent in the earth's atmosphere.
4. Prepare a report for the class which summarizes this information.

Concept #35 - To insure a safe landing on any astronomical body, the space vehicle would have to use a force against gravity to slow its descent.

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Experience A: Illustrating the operation of a retro-rocket

Materials needed:

balloon, long not round
ladder, 5' or longer
medicine dropper, without rubber bulb
triangular file
liquid petroleum burner
match
cloth
asbestos pad
rubber band
watch with second hand

What to do:

1. Cut the medicine dropper in half to obtain a short piece of glass tubing with a tapered end. Fire polish the cut end. (Review the instructions on cutting and fire polishing glass tubing in the chemistry unit.)

2. Insert the wider end of the cut medicine dropper into the neck of the balloon and secure it with a rubber band twisted around the joint.

3. Blow into the medicine dropper to inflate the balloon. Twist the neck of the balloon to keep the air from escaping. Roll a few turns of the rubber band onto the neck of the balloon to keep the balloon sealed.

4. Climb the ladder. Hold the balloon near the ceiling and drop it. Record the time required for the fall.

5. Repeat the timing 2 or 3 times and average the times recorded.

6. Place a finger over the end of the medicine dropper to close it as the rubber band is rolled back onto the medicine dropper. Hold the balloon near the ceiling and record the time required for it to fall to the floor.

Experience A (continued):

7. Repeat the timing 2 or 3 times and find the average of these times. (It is possible to change the rate of fall by using a larger or smaller opening on the tapered end of the medicine dropper.)
8. Compare the times required for the balloon to fall to the floor. Use the observations to develop an explanation for the use of retro-rockets to obtain a "soft" landing for a space vehicle.

**Experience B:** Review experience A for Concept #19

Experience C: Reviewing proposed plans to insure safe landings on the moon

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find information on the proposed Project Apollo.
2. Find information about the methods which have been suggested to slow the space vehicles descent to the surface of the moon.
3. Note whether they are methods different from those used to slow a space capsule's descent to the earth.
4. Prepare a report for the class concerning this information.

Concept #36 - Air resists the force which would put an object in motion.

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Experience A: Discovering air resists an object moving through it

Materials needed:

cardboard, 2' x 3'

What to do:

1. Go out onto the playground.
2. Hold the cardboard out flat in front of the body. Run rapidly for a short distance. Note whether much effort is required.
3. Stop to rest for one minute; then run slowly for a short distance. Note the amount of effort required.
4. Compare the amount of effort. Repeat the experience several times and compare again.
5. Explain the difference. Draw a conclusion relating the speed of movement of an object through the air to the amount of resistance from the air.
6. Explain how this experience illustrates one problem related to the return of space capsules to the earth's surface.

**Experience B:** Experiencing the air resistance acting on objects moving through air

Materials needed:

cardboard, about 2' x 3'
stop watch, or watch with second hand
pencil
paper

What to do:

1. Go out onto the playground.
2. Divide the children into equally sized groups.
3. Line one group up on each end of the playground.
4. Have one child run as fast as possible across the playground holding the cardboard out flat in front of him.
5. Have him hand the cardboard to the child at the head of the line. Have the second child run back to the other line. Record his time.
6. Continue passing the cardboard back and forth between the two lines until everyone has had a turn.
7. Find the average of the times.
8. Have each child run the same distance without carrying the cardboard. Record the time required for each.
9. Find the average of the times.
10. Compare the results. Draw conclusions concerning the effect of air resistance.
11. Explain the importance of this resistance to re-entry of a space capsule into the earth's atmosphere.

Experience C: Measuring the amount of air resistance produced by the same object moving at different speeds

Materials needed:

sipper straw, paper, or plastic
rubber band, narrow
cardboard, 1' x 1'
string, 3' long, 5 pieces
glue
pencil

What to do:

1. Go out onto the playground.
2. Punch a small hole in each corner of the cardboard. Tie one end of each string to each of the corners.
3. Knot the opposite ends of all four strings together.
4. Attach the rubber band to the knot.
5. Tie the fifth string to the other side of the rubber band.
6. Lay the straw along the length of the rubber band. Glue one end of the straw to one end of the rubber band or the knot.
7. Make a pencil mark on the straw to indicate the length of the rubber band when it is not stretched. Mark the straw at equal intervals towards the opposite end of the straw.
8. Grasp the single string on the rubber band.
9. Run, dragging the cardboard. Observe the straw to see how much the rubber band stretches.
10. Run at different speeds and observe whether the rubber band always stretches the same amount.
11. Summarize the results. Explain what information this experience provides about air resistance.

Experience D: Discovering the effect of currents of air on the effective air resistance

Materials needed:

cardboard, about 2' x 3'
stop watch, or watch with second hand
pencil
paper

What to do:

1. Go out onto the playground on a windy day.

2. Divide the children into equally sized groups.

3. Line one group up on one side of the playground so the wind is blowing directly on the children's backs.

4. Line the second group up facing the wind.

5. Have one child run as fast as possible across the playground holding the cardboard out flat in front of him. Record the time required.

6. Have him hand the cardboard to the child at the head of the line. Have the second child run back to the other line. Record this time.

7. Continue passing the cardboard back and forth between the two lines until everyone has had a turn.

8. Find the average of the times when running with the wind and the average for running against the wind.

9. Compare the results and draw conclusions concerning the effect of currents of air on objects moving through them.

Experience E: Measuring the effort required to overcome a resistance which simulates the effects of air resistance

Materials needed:

aquarium, large or wash tub
clothes pin (not spring type)
string, 5 pieces about 4" long
jar cap
spring scale
nail, 2 pennyweight
hammer

What to do:

1. Tie one end of a string around the top of the clothes pin. Make a loop in the opposite end of the string.

2. Fill the aquarium 3/4 full with water.

3. Hook the spring scale in the loop of the string. Place the clothes pin in the aquarium near one end.

4. Pull the clothes pin across the aquarium. Read and record the effort required.

5. Tie one end of each of the other four strings to the clothes pin. Adjust the location of the strings so that each string is about 90° around the clothes pin from the other strings.

6. Punch 4 holes at equal distances along the edge of the jar cap using the hammer to drive the nail through the metal. Take care not to make nail holes in the desk top.

7. Tie one string through each hole.

8. Start near one end of the aquarium and drag the clothes pin across the length. Read the spring scale and record the effort required.

9. Compare the observations and draw conclusions based on the results.

Concept #37 - The resistance caused by air moving over an object is called air friction.

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Experience A: Observing an increase in air friction with an increase of speed

Materials needed:

bicycle
automobile

What to do:

1. Go out onto the sidewalk.

2. Fan the air with a hand. Note whether it is possible to detect the air resisting the motion.

3. Ride the bicycle slowly down the block. Hold a hand out against the wind and observe whether the air resists this motion.

4. Ride the bicycle rapidly. Note the air resistance to a hand held up against the wind.

5. Ride in an automobile. Hold a hand out the window for a short distance taking care not to strike anything. Note whether the air resistance is strong.

6. Summarize the observations. Explain the differences in the amount of air friction observed.

Experience B: Studying the effect of air friction on a space capsule

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find information about the re-entry heat of space capsules.
2. Explain where the heat comes from.
3. Find whether suggestions that have been made propose ways to decrease air friction or ways to get rid of heat (or both).

Concept #38 - An object moving through air produces air friction.

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Experience A: Illustrating a method of decreasing air friction

Materials needed:

cardboard, corrugated, at least 3' x 3'
string, 5 pieces, about 3' long
scissors, 8"

What to do:

1. Punch a hole in each corner of a stiff piece of corrugated cardboard.
2. Tie a string to each corner and knot all four pieces together above the center of the cardboard. Tie a long string to the knot.
3. Grasp the string, placing it over a shoulder and run across the playground, noting whether the cardboard makes it hard to run.
4. Cut the cardboard into four equal sized pieces. Punch holes into the four corners of one piece and knot a different piece of string into each corner.
5. Repeat the experience with the smaller piece of cardboard.
6. Compare the amount of effort required. Relate the observations to the importance of reducing air resistance in rockets.

Experience B: Observing an effect of air friction

Materials needed:

paper, 5" x 8", lightweight

What to do:

1. Grasp both sides of one end of the 5" x 8" piece of paper and hold it in a horizontal position. Note that the paper drops downward toward the opposite end.

2. Hold the paper just below the lips. Blow horizontally over the paper. Observe what happens.

3. Blow slightly upward. Observe any changes. (The air follows the surface of the paper and appears to pull it up to the horizontal. The friction between the paper and the air is continuous as the paper stays in contact with the air stream.)

Experience C: Feeling the heat created by air friction

Materials needed:

bicycle tire pump

What to do:

1. Hold the pump firmly in place with your feet.
2. Direct the nozzle at the end of the rubber tubing toward some bare skin.
3. Pump vigorously.
4. Note whether the temperature of the skin changes as the rapidly moving gas rubs against it. (Although the air is slightly warmed by compression in the pump, any heat that may be observed is primarily due to the friction of the high speed gas rapidly moving in contact with a solid. In a descending or re-entering rocket, the heat created by air friction makes necessary the use of a heat shield.)

## Concept #39 - The density (concentration) of air affects the amount of friction.

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Experience A: Simulating an object moving through dense and rarefied air

Materials needed:

chairs
desks

What to do:

1. Crowd all the chairs and desks in the school room towards one end of the room.
2. Walk across the length of the room. Note whether it is more difficult to walk at the end crowded with the furniture.
3. Note in which part of the room there are more collisions with the furniture.
4. Compare this experience to what would happen to an object moving through air near the earth's surface and far from the earth's surface.
5. Explain how these results help explain a problem associated with space travel.

Concept #40 - The density of the earth's atmosphere decreases as the distance from the earth increases.

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Experience A: Review Experience B for Concept #3

**Experience B:** Learning about the change in density of the air with altitude

Materials needed:

reference materials (periodicals, encyclopedias)
paper
pencil

What to do:

1. Consult reference materials describing the discoveries made by artificial earth satellites having very elliptical orbits.
2. Find information about the density of the earth's atmosphere at various distances from the earth's surface.
3. Prepare a graph of the density against the distance.
4. Prepare a report for the class, summarizing the information.

Concept #41 - As the speed of a moving object increases in the atmosphere, friction and heat increase.

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Experience A: Repeat experience C for Concept #38. Vary the experience by attempting to detect a difference in the amount of heat produced as the rate of pumping is changed.

This experience may be repeated at a garage or "filling station," using their supply of compressed air. Be sure to arrange with the manager and secure permission to use the compressed air and nozzle.

**Experience B:** Detecting heat produced by friction (not air friction)

Materials needed:

bicycle
sandpaper, 2 pieces
matches, kitchen

What to do:

1. Rub both hands together. Note whether they become warm. Rub the hands more briskly. Note whether the amount of heat increases.

2. Place two pieces of sandpaper together with the rough surfaces in contact. Rub them back and forth slowly. Observe the heat. Rub the pieces of sandpaper together more rapidly. Note whether the amount of heat increases.

3. Rub a match slowly across a rough surface. Strike a match very rapidly. Explain the source of heat which causes the match to light.

4. Feel the temperature of the rear bicycle tire. Ride the bicycle rapidly across the playground. Brake quickly. Feel the temperature of the bicycle tire where it has skidded across the ground. Note whether the temperature has changed.

5. Identify the source of heat. Explain why the amount of heat increases as the speed increases.

Concept #42 - Speed and altitude both determine the amount of friction on space vehicles.

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Experience A: Simulating differences of air friction in dense and rarefied air

Materials needed:

water
sipper straw, paper or plastic
rubber band, narrow
cardboard, 4" x 4"
string, 1' long, 5 pieces
glue
pencil
aquarium

What to do:

1. Go out onto the playground.
2. Punch a small hole in each corner of the cardboard. Tie the end of one string to each of the corners.
3. Knot the opposite ends of all 4 strings together.
4. Attach the rubber band to the knot.
5. Tie the other string to the other side of the rubber band.
6. Lay the straw along the length of the rubber band. Glue one end of the straw to one end of the rubber band or knot.
7. Make a pencil mark on the straw to indicate the length of the rubber band when it is not stretched. Mark the straw at equal intervals towards the opposite end of the straw.
8. Grasp the single string on the rubber band.
9. Run, dragging the cardboard. Observe the straw to see how much the rubber band stretches.
10. Run at different speeds and observe whether the rubber band always stretches the same amount.

Experience A (continued):

11. Go indoors. Fill the aquarium about 1/2 full of water.

12. Drag the cardboard through the water slowly. Note the amount of stretch on the rubber band.

13. Drag the cardboard rapidly through the water. Observe the amount of stretch of the rubber band.

14. Assume the water represents the more dense air near the earth's surface and the air represents the rarefied air high above the earth's surface. Explain:

    a. How speed determines the amount of air friction.

    b. How altitude determines the amount of air friction.

Concept #43 - The greater the air friction, the more intense the resultant heat.

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**Experience A:** Repeat Experience A for Concept #41

## Concept #44 - Certain designs reduce friction.

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**Experience A:** Discovering that air follows the surface or shape of the object moving through it

Materials needed:

bottle, smooth cylindrical shape, clear glass
tape, cellulose
candle, 3" long approximately
matches
rubber band
punk or twist of paper
paper, 5" x 12"
cardboard, 8" square
cardboard, 5" long x diameter of bottle
balloon
glass tubing, 2" long

What to do:

1. Light the candle. Stick the candle to the cardboard by dripping 2 or 3 drops of melted wax 2" from one edge of the 8" x 8" cardboard. Place the base of the candle in the melted wax holding it upright until the wax hardens. Place the bottle near the center of the cardboard about 1" in front of the candle.

2. Insert the glass tubing into the mount and neck of the balloon. Twist the rubber band around the neck of the balloon to hold the glass in place.

3. Blow up the balloon. Twist the neck of the balloon to prevent the air from escaping.

4. Aim the glass tubing so it blows on the side of the bottle opposite the candle as the air escapes from the balloon. Untwist the neck of the balloon. Observe what happens to the candle flame.

5. Move the bottle farther away from the candle. Relight the candle. Observe the candle flame again, repeating steps 3 and 4.

6. Place the other piece of cardboard on end in front of the bottle on the side opposite the candle. Repeat the experiment. Observe the candle flame.

Experience A (continued):

7. Extinguish the candle. Remove the candle from the cardboard.

8. Tape the two ends of the paper together. Drop the circular loop of paper around the bottle.

9. Blow up the balloon. Aim the glass tubing so the escaping air blows on the side of the paper loop. Observe the shape of the paper in the air stream.

10. Repeat the experiment without the candle, using smoke from punk to show the flow of air around the bottle.

11. Summarize the observations. Draw conclusions concerning the importance of the shape of the space vehicle during blast-off and movement through the earth's atmosphere.

## Experience B: Measuring the air resistance of different shapes

(This activity is a modification of an activity suggested in Experiments in the Principles of Space Travel.)

### Materials needed:

wood block, 8" square and 1" thick
wood bit, 9/16" diameter
wood bit, 1/8" diameter
brace
dowel rod, 1/2" diameter, 6" long
wire, heavy, 6" long (coat hanger)
dowel rod, 1/4" diameter, 12" long
knife
wire, heavy, 3" long
pliers
hack saw
thumb tacks, 2
ping pong ball
washers, 3
thread
electric fan
tape, cellophane
pencil
paper

### What to do:

1. Drill a 9/16" diameter hole through the center of the wood block.

2. Drill a 1/8" diameter hole through the 6" dowel rod 1$\frac{1}{2}$" from one end.

3. Make a 5/8" diameter loop in the end of the heavy wire. Bend the loop to a right angle with the rest of the wire.

4. Push the 3" length of wire through the hole in the 6" dowel rod. Make a small loop in one end of the wire. Make a second loop in the opposite end of the wire.

5. Place the 6" dowel rod upright into the hole in the wood block with the wire and the hole which was drilled through the dowel rod towards the lower end.

6. Slide the loop in the 6" length of heavy wire over the dowel rod so that the loop of the wire is up. Push the straight end of the wire into the wood block close to the hole.

7. Cut a notch which is $\frac{1}{2}$" long and 1/8" deep at the exact center of the 12" dowel rod.

8. Glue the upper end of the 6" vertical dowel rod to the notch in the 12" dowel rod.

Experience B (continued):

9. Adjust the 3" wire which is through the hole in the 6" dowel rod to obtain equal lengths on each side of the dowel rod.

10. Place one rubber band around one end of the 3" wire. Hold the dowel rod in place to prevent it from turning. Fasten the farthest part of the rubber band to the wood block with a thumb tack so the rubber band makes a right angle with the wire.

11. Place the second rubber band around the opposite end of the 3" wire and tack it on the opposite side of the dowel rod to the wooden block at a right angle to the wire. (There should be no tension on the rubber bands.)

12. Make a hole in the ping pong ball which is ¼" in diameter. Push the ball onto one end of the horizontal 12" dowel rod.

13. Tie 3 washers together with a loop of thread. Slip the loop over the end of the horizontal 12" dowel rod opposite to the ping pong ball. Move the washers closer to or farther from the center until the vertical dowel rod is balanced.

14. Connect the electric fan to a source of electricity. Aim the fan at the ball from the side so the air pushes against the side of the ball which is in the direction of the thumb tack. Note that the dowel rod twists around.

15. Make a mark on the wood block in the direction the wire is pointing. Label the mark with a description of the shape. Turn off the fan.

16. Make a cone from a sheet of paper 6" x 6". Attach it to the ball with the pointed end away from the fan. Move the washers, if necessary, to re-balance the apparatus.

17. Turn on the fan. Make a mark to indicate the direction of the wire "pointer". Label this mark with a description of the shape. Turn off the fan.

18. Move the cone to different position on the ball. Repeat the measurement.

19. Make other shapes and repeat the experiment.

20. Summarize the results and draw conclusions regarding the effect of the shape of an object on the amount of air resistance.

Experience C: Measuring air resistance of a model of a satellite

Materials needed:

rubber balloon
glass tubing, 4" long
graph paper, $\frac{1}{4}$" grid
one hole rubber stopper
rectangular iron supports, 2
pencil
rubber band
masking tape
burette clamp
model of a satellite
(hollow plastic or balsa wood)
wire, picture, 6"
stiff cardboard, 8" x 8"
wax, "Sealstix"
ruler

What to do:

1. Insert the glass tubing through the rubber stopper. Review the procedure for this operation which is described in the chemistry unit.
2. Fasten the end of the balloon to the glass tubing by twisting a rubber band over the mouth of the balloon.
3. Support the rubber stopper in the burette clamp attached to the support. Turn the clamp until the tubing is horizontal.
4. Attach one end of the picture wire to the model space capsule with the wax.
5. Mount the graph paper on the cardboard so that the grids are parallel to and perpendicular to the bottom of the cardboard.
6. Draw two lines each of which are over a grid line, so that the paper is divided into four equal quarters.
7. Punch a hole which is centered over one of the lines through the cardboard near one edge.
8. Make a small U shaped bend in the other end of the picture wire at right angles to the length of the satellite model.
9. Insert the U shaped end of the wire through the cardboard.
10. Attach the cardboard to the other support with masking tape. Adjust the cardboard until the wire hangs along the vertical pencil line.

Experience C (continued):

11. Adjust the position of the burette clamp which is supporting the balloon assembly so that the tubing can act as a nozzle which points toward one end of the model satellite.

12. Blow up the balloon and allow the air to escape.

13. Note that the model moves away from the jet of air. Explain the observation.

14. Repeat steps 12 and 13. Mark the furthest distance along the horizontal line that the wire is moved.

15. Record the number of lines on the graph that are between the vertical line and the mark that was made.

16. Turn the model around so that the other end of the satellite is in the jet of air. Take care to blow up the balloon the same amount as previously.

17. Record the number of lines across which the wire moves.

18. Make a comparison of the distances traveled and relate this to the amount of air resistance of the satellite model. (Further learning could be obtained if different shaped models with different weights, or gases other than air are used. If the models obtained are too heavy, an electric fan or an air jet produced by a bicycle tire pump or insect spray gun may be used to produce a greater volume of air flow.)

Concept #45 - Man must be protected during space travel.

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Experience A: Reviewing the studies of the effect of space travel on biological materials

Materials needed:

reference materials, (newspapers, periodicals)
scissors

What to do:

1. Make a collection of clippings telling of the results of experiments testing the effects of space travel on living things.
2. Sort the clippings under the different headings.
3. Keep the collection up to date.
4. Prepare a report for the class which describes one danger; e.g., the effect of radiation on living things.

**Experience B:** Review Experience D from Concept #13

Concept #46 - Man cannot exist in space without controlling his immediate environment.

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Experience A: Demonstrating the importance of air to living things

Note: This experiment is too difficult for children to perform. It should only be done by the classroom instructor for the pupils after it has been tried privately and/or with skilled laboratory trained personnel assisting. The animal suffers no pain.

Materials needed:

glass jar, wide mouth, one gallon
  (restaurant pickle or mayonnaise jar)
white mouse
dish pan
water
tin snips
$\frac{1}{4}$" mesh hardware cloth, 6" x 6"
candle, 1"
wood block, 1" x 4" x 4"
hammer

What to do:

1. Light the candle. Drip a few drops of melted wax on one side of the wood block. Place the other end of the candle upright in the hot melted wax. Steady the candle until the wax solidifies.

2. Put 3" of water into the dish pan.

3. Test to be sure that the wood block floats and holds the candle upright above the water.

4. Cut the hardware cloth with the tin snips exactly to the inside diameter of the jar. Take care to trim the sharp edges.

5. Place the white mouse in the jar.

6. Roll the hardware cloth enough to allow it to be placed inside the jar. Allow it to unroll and fit it to the inside of the jar about 2 inches from the mouth.

Experience A (continued):

7. Light the candle.

8. Float the candle and wood block on the water.

9. Carefully invert the mouse and jar over the candle making sure the mouth of the jar is below the water and the hardware cloth does not slip down.

10. Observe the mouse as the candle burns and is extinguished. Remove the jar from the water immediately after the mouse has become unconscious. (If the mouse does not receive fresh air within 20 seconds of the time it becomes unconscious, it will die. Science experts assure us this procedure is painless and safe for the mouse if it receives oxygen within 20 seconds.) Observe what happens.

11. Explain why the mouse becomes unconscious and why it revives when the jar is removed.

12. Explain what gas or gases remain in the jar when the candle is extinguished. Use reference books, if necessary.

Experience B: Observing live material in a limited supply of fresh air

Materials needed:

coleus plant, potted, 2 of equal size
large jar with cover

What to do:

1. Place one plant whose soil is not too damp in the bottom of the jar.

2. Seal the jar tightly and place it on the window ledge. Place the other plant on the window ledge beside the jar. Water the plant on the window ledge sparingly.

3. Observe the plant daily for two weeks and note any differences in its appearance.

4. Explain why the plant in the pot becomes less healthy after a period of time. Use the results to explain the need of living things for fresh air.

Experience C: Observing live plant material in a weak partial vacuum with an increased concentration of carbon dioxide

Materials needed:

large jars, with covers, 2
paper
match
coleus plants, potted, 2 of equal size

What to do:

1. Place one plant, whose soil is slightly damp, in each of the large jars.
2. Close one jar tightly.
3. Twist the piece of paper into a loose wick. Light the paper and drop it into the second jar beside the pot.
4. Close the jar tightly.
5. Explain what factors are different in the two jars.
6. Place both jars on a window ledge. Observe the plants closely once a day for 2 weeks to note any differences in appearance.
7. Explain the results in terms of the factors which are different in the two jars.

**Experience D:** Observing an air containing object as a partial vacuum is formed around it

Materials needed:

rectangular iron support
wire gauze
burette clamp
balloon, (slender shape is more desirable)
match
flask, Florence, 500 ml, Pyrex
ring clamp
alcohol lamp
rubber stopper to fit flask
thread
water

What to do:

1. Put enough air into the rubber balloon to maintain its shape. Knot the end to prevent the air from escaping. Tie a thread to the neck of the balloon.
2. Place water to the depth of 1/2" in the flask.
3. Place the flask on the wire gauze supported by the ring clamp attached to the support. Grip the neck of the flask with a burette clamp to steady it.
4. Light the alcohol lamp. Heat the flask and water.
5. Push the balloon into the flask, keeping hold of the thread. (If the balloon is difficult to push in, place the balloon in the opening and allow the flask to cool slightly.) Adjust the thread so that the balloon hangs in the center of the flask above the water.
6. Stopper the flask tightly. Allow it to cool to room temperature.
7. Observe the change in appearance of the balloon.
8. Explain the change in the balloon and compare this change to predicted effects of a partial vacuum on the human body.

Experience E: Observing the effects of a partial vacuum on gas filled objects

Materials needed:

ball, rubber or plastic (gas filled, sealed) 7/8" maximum diameter
ditto fluid can with cover
alcohol lamp
water
ring clamp
wire gauze
rectangular iron support
dish pan
hot pad or oven mitten
match

What to do:

1. Fill the can with water a number of times to remove any ditto fluid that is in it. Empty the can. Place 1/2 cup of water in the can.
2. Place the can on a ring clamp which is attached to the support.
3. Heat the can and boil the water for two minutes.
4. Put the ball in the can. Seal the can with the screw cover.
5. Use a hot pad to grasp the can. Place it in the dish pan or sink and pour cold water over it.
6. Observe what happens to the can. Explain the observation.
7. Open the can and remove the ball. Examine it closely.
8. Explain any difference in the appearance of the ball. Compare the appearance of the ball with what is predicted will happen to a space traveler who is unprotected from the nearly perfect vacuum in space.

**Experience F:** Observing the effects of hot, humid air on live materials

Materials needed:

portable steamer or a teakettle with a spout
water
coleus plants, potted, 2 of equal size
reference materials (encyclopedias, textbooks)

What to do:

1. Procure a portable steamer. Fill it to its capacity and plug it in. The teakettle could be used on the hot plate.

2. Point the nozzle of the steamer towards one plant when the steam appears. Observe. Compare the appearance of the two plants after 30 minutes.

3. Have the children come and inhale the steam. Have them note how they feel. Try to decide whether the heat, the high humidity or both contribute to a feeling of discomfort.

4. Consult reference materials to find the effects of heat and high humidity on living material which is not especially adapted to these conditions.

**Experience G:** Observing live material with different amounts of water available

Materials needed:

coleus plants, potted, 3 having same approximate size
pencil
water

What to do:

1. Place 3 identical potted plants on the window ledge. Number each pot to make identification easier.

2. Water the plant in pot #1 adequately twice a week. Do not over water. Water the plant in pot #2 as often as necessary to keep the soil thoroughly soaked. Do not water the third plant in pot #3.

3. Observe the plants daily for two weeks and note any differences in their appearance.

4. Explain and summarize the observations. Compare the results to the effects of too much or too little water on a man.

Experience H: Observing the effect of severe temperatures on live material

Materials needed:

refrigerator
oven
coleus plants, potted, 3

What to do:

1. Place a potted coleus plant in a refrigerator freezing compartment.
2. Place a second plant in an oven heated to 350° Fahrenheit.
3. Set a third plant in a dark closet in the classroom.
4. Observe each plant every 5 minutes and compare the appearance of each of the plants. Stop after a definite change is noted in two of the plants.
5. Explain what caused the change in the two plants.
6. Explain what happens to a man who is exposed to severe temperatures.

Experience I: Experiencing an uncomfortable environment

Materials needed:

overcoats
pencil
paper

What to do:

1. Prepare two arithmetic tests of equal difficulty.
2. Have the children put on overcoats.
3. Sit in the classroom for 30 minutes. Have each child take an arithmetic test.
4. Have the children hand in the tests before removing their coats.
5. Have the children compare their comfort before and after the putting on of their overcoats.
6. Have the children take the second test after they have cooled off and had some diversion.
7. Correct both sets of tests. Note whether the children can do their school work as well when they are too warm.
8. Explain the observation. Draw conclusions concerning the efficiency of an astronaut when he is too uncomfortable. (It may be easier to do this experience by closing the windows and raising the thermostat to overheat the room.)

Experience J: Listing the conditions of the physical environment of space

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to obtain information about space.
2. Make a list of the conditions of the physical environment in space.
3. Consult references to discover what conditions are required by a man.
4. Explain why a man cannot exist in space without some kind of protection.

## Concept #47 - Vehicles for space travel must provide a desirable environment for man.

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**Experience A:** Studying the devices used to control the environment in a space capsule

Materials needed:

reference materials (periodicals, encyclopedias)
paper
pencil

What to do:

1. Consult reference materials to find the kinds of the environmental control systems included in the Friendship 7, Aurora 7, and Sigma 7.
2. Determine whether these control systems are similar to those used in a house.
3. Explain the importance of controlling the environment to the safety of the astronaut.

Experience B: Making a model space station

Materials needed: (see suggestions in section VI of this resource unit)

reference materials (periodicals, encyclopedias)

What to do:

1. Prepare a list of devices necessary to control the environment in a space station which can be sent into space in parts and joined together while in space.
2. Make a model of this kind of space station.
3. Use the model to illustrate a report to the class about the control devices necessary in a space station.

Experience C: Illustrating a method of simulating gravitational force in space stations

Materials needed:

water
pail
reference materials (periodicals, textbooks, encyclopedias)

What to do:

1. Partially fill a pail with water. Be sure there is no more water in the pail than can be lifted easily.

2. Go out onto the playground.

3. Swing the pail rapidly in a vertical circle. Observe what happens. (As long as the pail is kept moving, the water cannot fall out because it is pushing hard against the bottom, even when the pail is upside down overhead.)

4. Explain how the experience illustrates one method of creating artificial "gravity."

5. Consult reference materials to find information explaining why plans for a space station usually suggest a wheel shape which would rotate and have the work areas along the outside.

6. Suggest other methods of providing an artificial gravitational force in a space station.

## Concept #48 - Man is able to adapt to a slightly changed environment.

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**Experience A:** Discussing an adaptation to a slight change in environment

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
swing

What to do:

1. Survey the class to see if any of the children have taken a trip through the Great Lakes or a long ocean voyage.
2. Have the child describe the problems of walking on a moving surface. Have him explain the term "sea legs."
3. Explain how "sea legs" are an adaptation to a slightly changed environment.
4. Discuss whether an adaptation would be necessary to accommodate to a steady surface upon disembarking from the ship. Consult references to find information if necessary.
5. Have the child describe people who were "sea sick" during parts of the voyage.
6. Have each child in the class tell of his experience with motion sickness.
7. Go to a playground. Have a child who claims to be especially susceptible to motion sickness swing. Have another child who has never experienced motion sickness swing for the same length of time.
8. Observe the reactions of each child. Summarize the observations.
9. Consult references to find whether motion sickness decreases after a period of time.
10. Relate the conclusions concerning motion sickness to problems of spinning and tumbling space capsules.

Experience B: Adapting to a slightly changed amount of heat in our environment

Materials needed:

clothing
pencil
paper

What to do:

1. Set the thermostat in the room to below 65° Fahrenheit. Keep the room temperature below 65° Fahrenheit for a day or two. Note any changes in the amount and types of clothing which are comfortable.

2. Describe the changes in clothing which are made to fit weather conditions. Make a chart of the type of clothing worn and the weather condition, such as rain, snow, hot day, cold day.

3. Summarize the information concerning this method of adapting to a slightly changed environment. Explain why special clothing is designed for space travel.

Experience C: Discovering ways an environment is controlled

Materials needed:

pencil
paper

What to do:

1. Survey a house to discover the different ways the environment inside the house is controlled to avoid discomfort.

2. Prepare a list of the environmental factors controlled and the methods used to control them, such as, cold - furnace, heat - cooler, light - shades and curtains.

3. Prepare a report for the class which points out the similarities of the environmental control systems in a house to those necessary to a space capsule.

Experience D: Discovering some adjustments which are made to fit an environment

Materials needed:

reference materials (encyclopedia, periodicals)
pencil
paper

What to do:

1. Make a chart listing handicaps which some people have.
2. Consult references to find what adjustments are necessarily made by handicapped people in order to earn a livelihood and live among non-handicapped people.
3. List beside each handicap a method of adjusting to the handicap.
4. Take a field trip to a place especially designed for handicapped people or invite a handicapped person to talk to the class.
5. Discuss the value of these methods of adjustment to space pioneers who may be unable to do things in the usual manner.

**Experience E:** Becoming aware of adaptations which can be made for an environment which does not transmit sound

Materials needed:

pencil
paper

What to do:

1. Have everyone in the class (including the teacher) stop talking or making sound signals for half a day. Attempt to carry on the usual activities.
2. Note the difficulties which arise and the methods used to adapt to the change.
3. After the "silence period" is over, discuss these solutions in relation to their value to space pioneers who land on an astronomical body which has little or no atmosphere.
4. Compare the effectiveness of the solutions discovered by the class to the proposed use of radio for communication.

Experience F: Becoming aware of adaptations which can be made to suit environments which are not lighted

Materials needed:

blindfolds, clean

What to do:

1. Put on a blindfold for an hour or more. Attempt to carry on the usual activities.
2. Note the difficulties encountered and the methods used to adapt to the change.
3. Discuss these solutions in relation to their value to space pioneers who may land on the dark side of an astronomical body.

Experience G: Experiencing a slight change in the amount of light in an environment

Materials needed:

mirror, pocket sized

What to do:

1. Observe the size of the pupil of the eye using a mirror.

2. Go into a darkened room. Attempt to see different objects.

3. Note whether it is possible to see objects distinctly immediately upon entering the room.

4. Note that after a period of time, it is possible to see objects distinctly.

5. Use a mirror to observe the size of the pupil of the eye while in the darkened room.

6. Go into a totally dark room such as a photographer's dark room. Attempt to see different objects.

7. Observe the size of the pupil of the eye immediately after coming out of the dark room. Note that the size of the pupil changes rapidly.

8. Explain how a man is able to make this "dark adaptation" to a slightly changed environment.

9. Explain why ability to adapt to different brightness of light is important for a man during space travel.

Experience H: Experiencing a slight change in an environment's amount of light

Materials needed:

mirror, pocket sized
book

What to do:

1. Sit down in bright sunshine with a book.
2. Read for five minutes with bright sunshine on the printed page.
3. Use a mirror to observe the size of the pupils of the eyes.
4. Move into the shade of a building or a dense tree and read for five minutes.
5. Observe the size of eye pupils as before.
6. Compare the results.
7. Discuss how the ability to adjust to different intensities of light is important to a man during space travel.

**Experience I:** Studying the effects of inability to adapt to or become tolerant to a changed environment

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Consult reference materials about "snow blindness." Find the cause of "snow blindness" and methods of preventing it.
2. Explain what adaptation the human body has not been able to make to fit the changed environment.
3. Prepare a written report about "snow blindness," relating the problem to a problem of manned space travel.

Concept #49 - Man can live for a short period of time in a greatly changed environment.

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**Experience A:** Listing the conditions necessary for man to stay alive

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Consult reference materials to find what is needed to keep a man alive. Attempt to find data concerning the minimum and maximum requirement for each day.

2. Make a chart listing the environmental factor and the extremes which are permissible. Include environmental factors such as, oxygen, water, food, temperature, pressure, amount of radiation.

3. Indicate on the chart how long a man could live when too much or too little of each factor is present.

4. Draw conclusions concerning the length of time man can live in a greatly changed environment.

Experience B: Experiencing the effect of a cold environment

Materials needed:

ice
water, cold
dish pan
pencil
paper

What to do:

1. Fill the dish pan 1/2 full of ice. Add water to make ice water.
2. Immerse one hand in the water.
3. Describe and record the sensations felt in the hand.
4. Remove the hand from the water after 3 minutes.
5. Observe whether the hand is numb and whether the fingers are as able to grasp a pencil. (There will be different reactions by each pupil who tries this.)
6. Explain what has happened to the hand. Conclude what would happen to a man if his entire body was exposed to a much colder environment for a longer period of time. (Note: No cellular material is actually damaged by this short exposure to cold.)
7. Discuss what the conclusions indicate in regard to exposure to a greatly changed environment. Explain how the conclusions are related to the problem of man in space.

Experience C: Studying information related to survival in cold environments

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Consult reference materials written about the length of time aviators or sailors have been able to survive in:
   - a. freezing water without protection
   - b. freezing water with clothes for protection
   - c. freezing water with an aviator's suit for protection
2. Consult reference materials to find what kinds of clothing and shelter are necessary for survival in the Arctic and Antarctic.
3. Summarize the information about the effects of cold on the human body in a written report.
4. Consult references to find what temperature conditions exist in space.
5. Explain why a man would not be able to survive in space without protection from the cold.

**Experience D:** Experiencing the effect of substituting water for air in an atmosphere

Materials needed:

dish pan
water, at room temperature
towels
stop watch
pencil
paper

What to do:

1. Fill the dish pan 1/2 full of water.
2. Have each child put his head under water as long as possible. Have the teacher time how long each child is able to keep his head under water. Have the children use the towel to mop up the spilled and splashed water.
3. Find the average of the times. Explain why it is not possible to remain in a "water atmosphere" longer.
4. Discuss what would happen if a man were exposed to any kind of atmosphere other than air.
5. Explain how the results of this experience gives evidence for the need for providing a man an atmosphere which is only slightly changed during space travel.

Experience E: Studying data regarding the need for water

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Consult reference materials to find information about how long a man in the desert can live without water.
2. Find what minimum amount of water is necessary to sustain life under conditions of low humidity.
3. Explain how the data provides evidence that the environment within a space capsule must be carefully controlled.
4. Prepare a written report stating the evidence and the conclusion drawn.

Experience F: Discovering a water environment is not healthful to a man

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Review the reference materials which tell about long distance swimmers to find what special provisions must be made to protect them.
2. Find an explanation of the reason for greasing the bodies of the swimmers.
3. Weigh yourself before going swimming. Stay in the water for two or more hours. Weigh yourself immediately after swimming.
4. Explain why there is a change in weight. (It is possible to observe the effects of osmosis in another way by soaking a fresh egg in vinegar until the shell dissolves and then soaking the egg without the hard shell in water. Compare the size of this egg to another fresh egg still in its shell.)
5. Summarize the findings in a written report which emphasizes why a man cannot live long in a greatly changed environment.

Experience F: Discovering a water environment is not healthful to a man

Materials needed:

reference materials (encyclopedias, periodicals, recent books)
pencil
paper

What to do:

1. Review the reference materials which tell about long distance swimmers to find what special provisions must be made to protect them.
2. Find an explanation of the reason for greasing the bodies of the swimmers.
3. Weigh yourself before going swimming. Stay in the water for two or more hours. Weigh yourself immediately after swimming.
4. Explain why there is a change in weight. (It is possible to observe the effects of osmosis in another way by soaking a fresh egg in vinegar until the shell dissolves and then soaking the egg without the hard shell in water. Compare the size of this egg to another fresh egg still in its shell.)
5. Summarize the findings in a written report which emphasizes why a man cannot live long in a greatly changed environment.

Experience G: Studying the limiting factor for certain activities

Materials needed:

reference materials (encyclopedias, periodicals)
pencil
paper

What to do:

1. Consult references which discuss the following activities:

    a. Scuba diving

    b. Working as a "sandhog"

    c. Flying a plane at high altitudes

    d. Mountain climbing

2. Find what environmental factor or factors limit the height (or depth) which is safe.

3. Discover the meaning of:

    a. compression

    d. decompression

4. Summarize the information concerning limits to life in a written report.

5. Consult references to find what conditions exist in space.

6. Compare the conditions and draw conclusions based on the comparison.

Concept #50 - Man has to carry his own oxygen when traveling away from the earth.

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Experience A: Studying the methods of supplying oxygen to a space traveler

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find how much oxygen is required for one astronaut for one hour.
2. Find out where the oxygen was stored and how its rate of flow was controlled in Friendship 7, Aurora 7, and Sigma 7.
3. Find out how many hours would be required for a trip to the moon, exploration of the moon and the return trip.
4. Calculate the amount of oxygen which is required.
5. Read about plans for Project Apollo. Find an explanation of the methods suggested for supplying the oxygen.
6. Prepare a report for the class summarizing the information.

Concept #51 - Due to weightlessness in space travel, man may have problems with his breathing, drinking, eating and moving.

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**Experience A:** Experiencing difficulty in eating and drinking due to a change in position as related to gravity

Materials needed:

gymnasium mat
apple
cup, paper
water
chair
reference materials (periodicals, encyclopedias)

What to do:

1. Stimulate some of the effects of weightlessness by doing a hand or head stand against the stall bars on a gymnasium mat in gym. Have another child hold the feet against the stall bars for safety.
2. Try to eat from an apple or to take a sip of water from a cup while upside down.
3. Lean across the seat of a chair so that the hips are over the head.
4. Attempt to eat a piece of apple. Attempt to drink a cup of water.
5. Relate the difficulty of eating and drinking while upside down to the difficulty which space travelers may encounter.
6. Refer to descriptions of the experiences of astronauts Glenn, Carpenter, and Schirra to find out how well the problems of eating and drinking were solved.
7. Suggest other ways of solving the problem.

Concept #52 - Sustained weightlessness may cause many hazardous strains on the human anatomy.

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Experience A: Experiencing a moment of weightlessness

Materials needed:

none

What to do:

1. Ride on an elevator where there is a considerable drop as in Medical Arts Building or Foshay Tower.
2. Describe the sensation to others in class.
3. Explain how this experience simulates weightlessness during space travel.

Experience B: Reviewing the experimentation made on the use of methods of exercise during space travel

Materials needed:

reference materials (encyclopedias, textbooks, periodicals)
pencil
paper

What to do:

1. Read reference materials to find descriptions of fakirs in India who abuse their own body. Find whether any of them cause their muscles to become useless (atrophy). Discuss what causes the muscles to atrophy.
2. Consult a resource person who is working in occupational therapy. Find what the purpose of therapy treatments is.
3. Consult reference materials describing Astronaut Carpenter's flight. Find out why he used an exercising band.
4. Explain why weightlessness might cause muscles to atrophy.

**Experience C:** Studying methods of simulating gravitational attraction in a space station

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find information about the known effects of weightlessness on a man.
2. Review Experience C for Concept #47.
3. Discuss the need for metallically weighted shoes and special suits to compensate for variations in the weight of the astronauts.
4. Suggest which method or methods would be most effecttive in eliminating each hazard listed in step 1.

## Concept #53 - The radiant energy from the sun may be dangerous to a man in interplanetary space.

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**Experience A:** Observing an effect of one kind of the sun's radiant energy

Materials needed:

paper, black
paper, white
thermometers, Fahrenheit or centigrade, 2

What to do:

1. Obtain a piece of white paper and a piece of black paper of the same thickness.
2. Place them on a window ledge in the sunlight.
3. Push a thermometer under each piece of paper.
4. Wait 20 minutes and read the temperature indicated by each thermometer.
5. Explain why the thermometers indicate different temperatures and identify the source of the heat.

Experience B: Measuring the difference in the effect of heat energy on protected and unprotected material

Materials needed:

cans, frozen juice, 2
water, at room temperature
thermometers, Fahrenheit or centigrade, 2
paint, black, flat

What to do:

1. Wash two empty frozen juice cans with water. Dry them carefully.
2. Paint one can black with flat paint.
3. Fill each can with water which is at room temperature.
4. Place a thermometer in each can. Observe the temperature of the water and record it.
5. Place both cans in the sunlight and allow them to stand an hour.
6. Observe and record the temperature of the water.
7. Compare the initial and final temperatures.
8. Identify the source of the heat which raises the temperature of the water. Explain why the temperature differences in both cases were not equal.
9. Explain the importance of this effect on plans for controlling the heat in a space vehicle.

Experience C: Discovering the danger from the sun's energy is different at different distances from sea level

Materials needed:

reference materials (periodicals, encyclopedias, textbooks)
pencil
paper

What to do:

1. Read reference materials to find comparisons of the rate of getting sunburned at sea level and on a mountain top.
2. Decide whether sunburn is greater close to the earth's surface or above the earth's atmosphere.
3. Make a report for the class which explains what kind of protection this information indicates would be needed by a man in space.

**Experience D:** Listing the dangers from the sun's energy and ways to prevent injury

Materials needed:

reference materials (periodicals, encyclopedias, textbooks)
pencil
paper

What to do:

1. Consult reference materials providing information about the sun's radiant energy.
2. Make a chart listing the kinds of radiations from the sun producing dangerous results on the human body; e.g., heat, ultraviolet light.
3. Discover the ways a man is protected from these dangers on the earth's surface.
4. Suggest ways a man could be protected from these radiations while in space.

Concept #54 - Man will have to establish an artificial environment in order to survive on the surface of other astronomical bodies.

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Experience A: Surveying conditions known to exist on planets other than the earth

Materials needed:

reference materials (periodicals, encyclopedias, textbooks)
paper
pencil

What to do:

1. Consult reference materials to find information about the planets in the solar system.
2. Make a chart listing each of the planets.
3. Indicate the hottest temperature and coldest temperature on each planet.
4. Indicate whether each planet has oxygen in its atmosphere.
5. Imagine an expedition is planned which will go to all the planets. Explain what provision a man must make to insure a suitable temperature and a supply of oxygen needed to sustain life on each planet.

**Experience B:** Showing a collection of recent suggestions for living quarters on other astronomical bodies

Materials needed:

newspapers and magazines, recent
paper
pencil
reference materials (periodicals, textbooks, encyclopedias)

What to do:

1. Collect clippings from recent magazines and newspapers about living on other astronomical bodies.
2. Consult other references to find further information.
3. Make a mural or booklet with pictures and reports describing the type of environment man would have to devise to live on the moon or in some other alien environment.
4. Make a report to the class about this information.

Experience C: Making a model of a proposed "moon city"

Materials needed:

stovepipe wire
pliers
transparent material (plastic sheets, cellophane, Saran Wrap)
cellophane tape
reference materials (periodicals, encyclopedias)

What to do:

1. Consult reference materials to find suggestions for a "moon city."
2. Form the wire into the desired shape.
3. Make a dome of transparent material fitted over a wire frame.
4. Build a model city. Use the dome to cover a model city to show an artificial environment needed on the moon.
5. Explain why a dome is necessary to the city.

Concept #55 - Space vehicles need to be protected against bombardment by meteors and cosmic dust.

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**Experience A:** Finding the results of an experiment on the dangers from meteors and cosmic dust during space travel

Materials needed:

reference materials (periodicals, encyclopedias, textbooks)
pencil
paper

What to do:

1. Consult reference materials describing the Echo I project.
2. Find the purpose of the project and an evaluation of the information gathered.
3. Explain whether there is danger of a space vehicle impacting with meteors. Explain what micrometeors are.
4. Make a report to the class summarizing the information.

## Concept #56 - Rockets must be made of materials which withstand heat and stress.

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**Experience A:** Observing an effect of stress due to acceleration

Materials needed:

bricks, 3 (or small rocks)
paper sack

What to do:

1. Place the bricks in a paper sack on the floor.
2. Grasp the sack at the top. Lift the sack slowly.
3. Observe whether anything unusual happens.
4. Replace the sack and bricks on the floor.
5. Raise the sack very rapidly. Repeat increasing the lifting speed until something unusual happens.
6. Explain the difference between the first and last observations.
7. Explain how this demonstrates one source of the stresses which acts on rockets at blast-off.

**Experience B:** Experiencing stress due to acceleration

Materials needed:

automobile
driver

What to do:

1. Ride in the family automobile without safety belts fastened. Have the driver rapidly stop and start the car.
2. Observe which direction the occupants move as the car starts up. Observe the direction the occupants move as the car stops.
3. Can you discover the reason for the use of safety belts in automobiles?
4. Summarise the observations to obtain an understanding of one source of the stresses on a space vehicle and astronaut at take-off and when the retro-rockets are fired.

Experience C: Observing an example of stress due to twisting (torque)

Materials needed:

clothes hanger

What to do:

1. Grasp the hook on the clothes hanger.
2. Twist the hook back and forth a number of times. Note that eventually the metal hook breaks off.
3. Explain how this example of repeated stresses illustrates the need for special materials for resistance to twisting of guidance fins on a rocket.

Experience D: Observing shear on metal fastenings

Materials needed:

aluminum sheets, 2
bolts, aluminum, 2
bits, for metal
drill

What to do:

1. Obtain two sheets of aluminum. Drill two holes in each sheet near one end, 3 inches apart.

2. Lay the two drilled ends of the pieces of metal on top of one another so that they overlap as little as possible.

3. Bolt the pieces of metal together with two aluminum bolts.

4. Grasp the opposite ends of each metal piece and move the metal pieces back and forth across one another for a period of time.

5. Observe what happens to the bolts.

6. Compare the effect of the sheet metal on the bolts to the cutting action of shears.

7. Explain how the thin pieces of metal cutting through the bolt is related to the problem of joining parts of a rocket together.

Experience E: Observing stress due to angular momentum

Materials needed:

pebbles
paper sack

What to do:

1. Go outside into the school yard. Stand away from the members of the class and the school windows.
2. Place approximately five pounds of pebbles in a paper sack.
3. Grasp the sack at the top. Swing the bag slowly in a vertical circle.
4. Observe what happens.
5. Increase the speed of the bag until it is swinging as rapidly as possible.
6. Observe what happens. Explain how this experience can be used to gain an understanding of one of the stresses on a space vehicle.

Experience F: Observing the stress on an object following an orbital path

Materials needed:

steel ball bearing, ¼" diameter
balloon
string, 3' long
camera, with shutter speed of 1/100 second or faster
scissors

What to do:

1. Snip off the end of the opening of the balloon.

2. Place the ball bearing into the balloon as a weight.

3. Tie one end of the string tightly around the opening of the balloon.

4. Go out onto the playground far from the school building. Make sure no one stands on either side of the experimenter; however, they may stand in front or behind the experimenter. (There is some danger that the balloon will stretch too far and break. The steel ball would leave the circle much as a stone leaves a sling shot. Take care that nothing would be in the way of the flying ball bearing.)

5. Hold the free end of the string in one hand with the balloon hanging down. Extend the index finger of the other hand horizontally at waist level.

6. Photograph the weighted balloon and the finger.

7. Swing the weighted balloon rapidly on the end of the string in a vertical circle in front of the experimenter.

8. Photograph the extended index finger and the weighted balloon when the balloon reaches the lowest point of circle.

9. Use a ruler to measure the length of the index finger in both photographs to be sure the scale is the same in both cases.

10. Measure the length of the weighted balloon in each picture. observe whether the balloon's length is changed. Correct the two lengths if the index finger lengths are not equal.

11. Draw conclusions based on the observations regarding the reason for the lengthening of the balloon while orbiting.

Concept #57 - A rocket begins to rise very slowly because of the forces which must be overcome; e.g., inertia.

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Experience A: Illustrating the purpose and path of a rocket putting a space capsule into orbit

Materials needed:

reference materials (periodicals, encyclopedias)
cotton flannel board
flax
tight wool cutouts of parts of 3 stage rocket and capsule and part of the earth's surface

What to do:

1. Ask the class to take an imaginary trip into orbit around the earth. Illustrate the trip on the flannel board.
2. Explain the purpose of each stage of the rocket. Show the path the capsule follows. Show how the rocket is aimed so the first stage can serve the purpose of getting the rocket out of most of the earth's atmosphere. Show how the second stage is used to gain altitude and speed. Show how the third stage gives the rocket the right direction and speed for orbiting.

**Experience B:** Doing a "magic trick" which illustrates an effect of inertia

Materials needed:

paper, strip, $1\frac{1}{2}$" x 6"
pencil, with the eraser cut off to give a flat end, 3"
table

What to do:

1. Place one end of the strip of paper on the table. Balance the pencil on its end on the paper.
2. Moisten the finger tips. Swing the hand rapidly so the fingers brush against the paper. Observe what happens.
3. Replace the paper under the pencil and repeat the observation.
4. Explain the results identifying the force acting on the pencil.

Experience C: Observing the effects of both kinds of inertia

Materials needed:

building brick
string, 6" long, several lengths
string, 8" long
ring clamp
rectangular iron support
"C" clamp
table

What to do:

1. Tie a 6" string securely to each end of the brick.
2. Attach the ring clamp near the top of the rectangular iron support. Clamp the support securely to the table top with the "C" clamp.
3. Turn the ring clamp so that it hangs over the edge of the table.
4. Tie one of the strings attached to the brick onto the ring stand. Tie the 8" string to the ring stand and the brick leaving a little slack in the string.
5. Grasp the lower string tied to the brick. Give a rapid, strong pull on the string. Observe what happens.
6. Replace the broken string. Repeat several times to determine whether the same thing happens each try.
7. Grasp the lower string tied to the brick. Give a slow, steady pull on the string. Observe what happens.
8. Replace the broken string. Repeat several times to determine whether the same thing happens each try.
9. Explain why different results are obtained in step 6 and step 8.

**Experience D:** Observing an effect of inertia

Materials needed:

deep upholstered armchair

What to do:

1. Have a child sit in the deep upholstered armchair.
2. Have the child rise from the chair. Note whether he lifts himself more slowly at the beginning or near the end of the movement.
3. Explain what force resists the movement.
4. Repeat the experience at the end of the day to develop an understanding of the effects of fatigue on an individual's movements.

**Experience E:** Reviewing the blast-off time of a rocket

Materials needed:

reference materials, (replay of the broadcast of the beginning of an astronaut's flight)
film, "Screen News Digest No. 8" or a more recent film
motion picture projector, 16 mm
projection screen

What to do:

1. View a recent film or listen to a rebroadcast of the beginning of an astronaut's flight.
2. Note the rocket seems to remain motionless for one or two seconds after ignition. Observe whether the rocket gains speed.
3. Explain how the observations are the result of forces which must be overcome before movement is possible.
4. Prepare an oral report explaining the observations for the class.

**Experience F:** Finding the direction of a rocket affects its speed

Materials needed:

wagon
ball
catcher's mitt
globe, terrestrial
model rocket

What to do:

1. Have a child wearing a catcher's mitt catch balls thrown by a child in a wagon which is being moved towards the center.
2. Have the child throw the ball a second time with the same force from exactly the same distance as the wagon is pulled away from the catcher.
3. Compare the speed of the ball each time. Explain why the ball travels faster during one try.
4. Hold the model of the rocket on the globe. Turn the globe from west to east.
5. Decide whether the rocket would travel faster if aimed east or if aimed west.
6. Explain to the class the effect of the earth's rotation and the rocket's direction on the speed of the rocket.

Experience G: Making a reaction engine

Materials needed:

carbon dioxide cartridge
firing pin for cartridge
wire, piano, length of room
paper clips, 2
string, 6", 2 pieces

What to do:

1. Fasten the piano wire to one wall of the room. Pull it taut and fasten the other end to the opposite wall.

2. Loop the center of each string around the cartridge and tie it tightly; one near the nozzle and the other near the opposite end. Make a loose loop in each string by tying the two ends of the string together.

3. Push the two paper clips onto the wire and attach them to the loose loops on the cartridge.

4. Adjust the string and paper clips so the cartridge hangs horizontally near one wall free from the wire and is aimed towards the opposite wall.

5. Puncture the cartridge and observe what happens.

6. Explain the observation. Compare the method of propulsion to the method used for rockets.

Experience H: Making a simple reaction motor depending on a chemical reaction

Materials needed:

soda pop bottle
baking soda
vinegar
water
broom
cork, to fit bottle
waxed paper, 4" x 4"
string, 2' long, 2 pieces
chairs, 2
tablespoon

What to do:

1. Fill the bottle to a depth of 1" with water. Add vinegar to increase the depth to 1½".
2. Place a tablespoon of baking soda on the waxed paper. Roll the paper into a cylinder and twist each end closed.
3. Knot one end of a string around each end of the bottle.
4. Place two chairs facing each other close enough to lay one end of the broom on each chair seat.
5. Adjust the lengths of the strings to suspend the bottle horizontally from the center of the broom.
6. Insert the rolled piece of the waxed paper containing the baking soda into the bottle.
7. Cork the bottle tightly immediately. Observe what happens.
8. Explain the observations.
9. Apply the results to an explanation of the method used to propel rockets.

Experience I: Observing a reaction engine in operation

Materials needed:

dowel rods, ¼" diameter, 12" long
brace
bit, 1/4" diameter
wood block, 8" x 8" x 1" thick
match
candle
tin snips
tin can
nail, brad
thread
washers, 6
knife
small metal can, airtight (tooth powder, spice)
wire, 9", 2 pieces
needle
cork
hammer
thumb tacks, 4
wood block, 2" x 3" x ½" thick
glue
pliers

What to do:

1. Drill a 1/4" hole through the center of the 8" x 8" wood block.
2. Force one dowel rod into the hole. Use glue, if necessary, to make sure the rod remains upright.
3. Cut a notch, 1/8" deep and 1/2" long in the center of the other dowel rod.
4. Cut a 1/4" wide strip of metal from the tin can which is very slightly longer than 1/2". Push the metal strip into the notch in the dowel rod.
5. Hold the point of the brad in the center of the metal strip. Tap the brad gently to obtain a dent (dimple) in the metal.
6. Tie the washers together in a loop of thread.
7. Push the needle through the cork so that the point extends 1/4" beyond the cork. Use a hammer to drive the needle through the bottom of the can near one edge.
8. Pull the needle out of the cork. Push the eye end of the needle into the end of the dowel rod mounted in the 8" x 8" wood block so that it points straight up.
9. Twist a 1/4" diameter loop into the center of each length of wire.

Experience I (continued):

10. Lay the can on its side. Turn the can so that the needle hole is up. Wrap each end of the one wire $1\frac{1}{2}$ times around the can near one end. Wrap the other wire around the other end of the can.

11. Tie a loose loop of thread through the two small loops of wire.

12. Push two thumb tacks, one near each end, into the side of the 2" x 3" wood block. Push the other two thumb tacks into the other side opposite the first two tacks. Twist one free end of the wires around each thumb tack. Adjust the length of the wires so the can hangs horizontally when suspended from the thread loop.

13. Light the candle. Drop hot wax in the center of the top of the small wood block. Extinguish the candle. Place the base of the candle in the wax and hold it steady until the wax hardens.

14. Place a teaspoonful of water in the can. Close the can.

15. Rest the dent in the free dowel rod on the point of the needle. Hold the rod to keep it from falling.

16. Hang the can, and candle from one end of the dowel rod. Hang the washers from the opposite end.

17. Move the washers along the length of the rod until the rod balances with the end supporting the can slightly lower than the horizontal.

18. Push gently against the side of the dowel rod to be sure it turns smoothly. Stop the moving arm.

19. Light the candle. Observe what happens after the water begins to steam.

20. Explain how the results illustrate the operation of a reaction motor such as found in rockets.

Experience J: Observing an example of the force created by rapid combustion

Materials needed:

corn starch
coffee can, 1 lb. size
funnel, small, short stem
cake pan, about 8" x 8"
oven
teaspoon
rubber hose, to fit tightly over stem of funnel,
 about 2' long
candle, 1" long
modeling clay
nail, 6 pennyweight
hammer
metal-working file (rasp)
books, about 12
match

What to do:

1. Pound the nail through the bottom of the coffee can half way between the center and the side. Twist the handle of the metal file into the hole to enlarge it enough to allow the stem of the funnel to slip through the hole.

2. Make two piles of books high enough to allow room under the can for the stem of the funnel and the rubber tubing. Support the can between the two piles of books.

3. Open the can. Slip the stem of the funnel through the hole from the inside of the can.

4. Attach the rubber tubing to the funnel. Hold the clay around the stem of the funnel to make the can airtight.

5. Use a small amount of modeling clay molding it around the base of the candle to hold the candle upright in the can.

6. Heat the oven to approximately 250° Fahrenheit. Place a teaspoonful of corn starch in the cake pan. Jiggle the pan to spread it over the entire surface. Place the pan in the oven, continually shaking the pan, for a few minutes to dry the corn starch. Remove the pan from the oven and turn off the oven.

Experience J (continued):

7. Place 1/2 teaspoon of dry corn starch in the funnel. Light the candle.

8. Close the coffee can tightly. Puff air into the free end of the rubber tubing. Observe what happens.

9. Explain the observations. Relate the results to the method of creating force in a rocket.

Experience K: Discovering the relationship of gravity and orbital velocity

Materials needed:

phonograph turntable, 3 speed
plywood, 5/8" thick, circular, 12" max. diameter
dowel rods, 3/4" diameter, 4" long, 2
screw eyes, ¼" long, 2
brace
bit, wood, 3/4" diameter
bit, wood, 1/4" diameter
spring scale
ball, 1/2" diameter, rubber
ball, 1" diameter, rubber
fish line, about 2 feet
glue, casein type

What to do:

1. Drill a 1/4" diameter hole through each dowel rod about 3/4" from one end.

2. Drill a 1/4" diameter hole 1/2" into the opposite end of one of the dowel rods.

3. Drill a 3/4" hole through the center of the plywood and a second 3/4" hole, 1/2" from the edge.

4. Insert the dowel rod with the two drill holes into the center hole of the plywood with the hole drilled into the end of the dowel rod on the underside so that the phonograph spindle fits into this hole. Make sure the rod is vertical and flush to the bottom of the plywood. Glue it in place.

5. Cut 12" of fish line. Knot one end of the string into one screw eye.

6. Weigh each ball and record the weights.

7. Twist the screw eye into one of the rubber balls.

8. Thread the fish line through the hole in the upper end of the vertically mounted dowel rod.

9. Attach this piece of fish line to the other ball using the other screw eye.

Experience K (continued):

10. Start the phonograph turntable and adjust the distance of each ball so that they are extending straight out as they rotate. Increase the speed of the turntable if necessary.
11. Measure the distance of each ball from the center.
12. Compare the distances to the weights of the balls.
13. Cut the fish line about 5" from the smaller ball.
14. Insert the other dowel rod into the hole in the side of the circular piece of plywood, keeping the 1/4" diameter hole drilled through the dowel rod at the top.
15. Glue it in place. Push the free end of the fish line attached to the smaller ball through the 1/4" diameter hole and tie the ball to this dowel rod on the side of the circular plywood.
16. Start the record player at slow speed.
17. Observe the position of the ball.
18. Increase the speed of the turntable and observe any changes.
19. Repeat steps 15 to 18 using the larger ball.
20. Summarize the observations. Attempt to express the results as a rule.

Note: An old phonograph record may be used in place of the circular plywood disc; however, it would not be as thick and greater care may be required to attach the dowel rods.

Experience L: Demonstrating the relation of the orbital velocity to the force which is acting to move the object away from the center of revolution (Note: In this experience the amount of stretch in the elastic string is used as a quantitative measure of the force.)

Materials needed:

rubber ball, attached to an elastic string - (part of a game, made of paddle connected to a ball with a long piece of elastic rubber string)

What to do:

1. Go out on the playground. Stand near a wall of the school building which does not have windows.
2. Tie a small loop in the end of the elastic string opposite to the ball. Insert a finger into the loop and grasp the elastic string firmly.
3. Swing the ball slowly over the head in a horizontal circle. Count and record the number of revolutions in one minute.
4. Continue revolving the ball at the same speed and walk towards the wall of the building until the ball just touches the building on each revolution.
5. Mark your position on the ground so that it is possible to measure the distance to the building when the experience is completed.
6. Move away from the building. Swing the ball again in a horizontal circle but this time swing it more rapidly. Count and record the number of revolutions per minute.
7. Keep the ball revolving at the new speed. Move towards the wall of the building again until the ball just touches it on each revolution.
8. Mark this second position on the ground.
9. Measure the radius of the circle made by the ball in each trial.
10. Grasp a piece of the elastic string between each hand. Pull your hands apart gently and observe. Pull your hands on the elastic string apart more strongly and observe.

Experience L (continued):

11. Note that a gentle pull does not stretch the rubber string as much as a strong pull.

12. Make a graph which relates the orbiting velocity (number of revolutions in one minute) to the amount of pull (length of the rubber string when stretched which is measured by the radius of the circle) in the two trials.

13. Explain how this illustrates the fact that a more swiftly orbiting object is able to pull harder against the gravity of the earth.

14. State the conclusion as a comparison of the orbital speed to the amount of outward pull on the orbiting ball.

Note: Satellites are sent into orbit at a speed sufficient to balance the amount of the satellite's fall towards the center of the earth with the force of the satellite's trying to go in a straight line path which is tangential to the earth.

## Concept #58 - Space ships require many instruments to guide them.

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**Experience A:** Discovering that slight adjustments in the direction of movement of rapidly moving vehicles produce the same amount of change as greater adjustments on slowly moving vehicles

Materials needed:

bicycle
hill, gentle slope
hill, steep slope

What to do:

1. Ride the bicycle slowly down the gentle hill and rapidly down the steep hill. Turn the front wheel from side to side during each ride.
2. Observe how much the front wheel must be turned to make a turn at each speed. Compare the amount the front wheel must be turned to go around the same kind of corner.
3. Use these observations to draw conclusions concerning the size of fins and the amount of movement of these fins which would be required to change the direction of movement of a high speed rocket.

Experience B: Observing simple examples of a guidance system

Materials needed:

top
book
gyroscope

What to do:

1. Start a top spinning on the surface of a book.
2. Lift one side of the book slightly.
3. Observe whether the top continues to spin straight up and down or whether it tilts with the book.
4. Start a toy gyroscope spinning.
5. Move it to a different position and observe whether it spins in a new direction or if it continues spinning in the same direction.
6. Explain why a gyroscope would be a valuable instrument to guide a space vehicle.

Experience C: Discovering the importance of aim in reaching a moving object

Materials needed:

ball

What to do:

1. Go outside into the playground.
2. Throw a ball to a child.
3. Observe the direction that the ball is thrown.
4. Have the child run as you throw the ball to him.
5. Observe whether the ball is thrown towards where he is when it leaves your hands or towards where he will be when it reaches him.
6. Throw the ball too far in front of him or towards where he is when the ball is released. Observe what happens.
7. Explain how this illustrates the problem of aiming a space vehicle.

**Experience D:** Experiencing a problem related to a problem of space travel

Materials needed:

merry-go-round in a park playground
ball

What to do:

1. Have two children sit on opposite sides and play catch with them.

2. Start the merry-go-round moving. Throw the ball to each of the children. Have them throw the ball to each other.

3. Exchange positions and continue until each has had experience throwing:

   a. from a stationary place to a moving place

   b. from a moving place to a stationary place

   c. from a moving place to another moving place

4. Compare the observations. Explain how this illustrates some of the problems of aiming a rocket.

Experience E: Discovering a method of determining location in space

Materials needed:

balloons, 3
strings, various lengths, 3
ladder, about 5' tall

What to do:

1. Blow up all three balloons. Knot the neck of each balloon.
2. Tie one end of a string to the knot in one balloon.
3. Hang the balloon from the ceiling.
4. Repeat steps 2 and 3 with the other balloons hanging them from the ceiling at different places and at different heights around the room.
5. Stand at one place in the room and draw a diagram of the location of the balloons by making 3 dots on a piece of paper.
6. Move to a different place. Draw a new diagram.
7. Lie down on the floor and diagram the balloon.
8. Stand on a ladder and diagram the balloons.
9. Compare the diagrams to see if they are identical.
10. Go back to each place in turn and make a new diagram.
11. Compare the two sets of diagrams. Discover whether there are pairs of diagrams.
12. Explain how this method could be used to navigate in space.

**Experience F:** Classifying guidance and control equipment for space vehicles

Materials needed:

reference materials (periodicals, encyclopedias)
pencil
paper

What to do:

1. Consult reference materials to find out about the instruments used to aim, guide, and control space vehicles.

2. Group the instruments into two groups:

    a. instruments in or on the space vehicle

    b. instruments on earth

3. Indicate the purpose of each instrument in a group beside its name.

4. Suggest reasons why all the equipment is not on the space vehicle.

Concept #59 - High speed in space travel is desirable to cover great distances in a convenient time.

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Experience A: Calculating the time required to travel to nearby planets and to the nearest star

Materials needed:

chart, "Some Astronomical Facts and Approximations for
Teaching," Appendix A
pencil
paper

What to do:

1. Consult the chart, "Some Astronomical Facts and Approximations for Teaching," to find the distance from the sun to Mars and to Venus.
2. Calculate the distance from the earth to Mars and to Venus by subtraction (assume the closest distance between them).
3. Find the distance from the earth to the moon.
4. Assume a space vehicle can travel 25,000 miles in one hour. Calculate the distance it could travel in one day.
5. Calculate the number of days required to travel to Mars, to Venus, and to the moon by dividing their distance by the answer found in step 4.
6. Use the distance to the nearest star calculated in Experience B for Concept #6 to calculate the time which would be required to go to the nearest star.
7. Repeat the experience assuming a speed of 500 miles in one hour which is approximately the speed of some commercial airplanes.
8. Explain why high speeds are very important for travel in the universe.

V. Review of the Unit

Have the class view the instructional motion picture film, "Research by Rockets" as a review.

(Do not use this film with slower learners since it is difficult.)

## VI. Suggestions for Construction Projects

Note: The construction projects are not of much scientific value unless they are done very carefully to scale. These scale models are good devices for motivating factual reading and close study of illustrations and other visual materials. They arouse interest and lead to creative thinking about the problems inherent in this unit. Much of the actual work can be done in the activity period or correlated with art.

### A. Space capsules and rockets

1. Floor models can be constructed out of large cardboard cartons, such as those used by moving packers. These can be covered with brown paper or corrugated paper to simulate metal and give the illusion of a cylindrical shape.

2. Table models can be constructed out of cylindrical cardboard cartons used for packing oatmeal. The economy size is very good for this purpose. More than one container can be utilized by removing bottom from the additional cartons which then can be placed on top and taped (masking tape) so all the cartons are held together. Three cartons can be utilized for three stage rockets. Cartons should be covered with brown wrapping paper or construction paper to simulate metal. Fins or legs at the bottom can be made from oak tag or construction paper with pliable wire (similar to that used for wire sculpture) worked in to provide strength for the fin frame. Pipe cleaners also work here in place of wire.

### B. Space Stations

1. A wheel shaped station can be constructed from paper rolled and attached to a pliable wire frame.

2. Cardboard cylinders used as foundation for wax paper, Saran Wrap, or aluminum foil work very well as construction material for a wheel shaped space station model. Smaller cylinders from toilet tissue rolls work very well for spokes of the wheel.

## VI. Suggestions for Construction Projects (continued)

### C. Dioramas

A cylindrical shape to give an interior view of a ship can be attained by cutting an oatmeal carton lengthwise and fitting a half section into a shoe box or other rectangular frame.

### D. Furniture

Scale models of the furniture for the space capsule, space stations or diorama can be constructed out of toothpicks or matchsticks glued together or molded clay. These can be covered with material scraps.

### E. Astronauts

Scale models of the astronauts can be constructed from paper mache. The figures also can be made from pipe cleaners.

### F. Clothes

Clothes for the models of the astronauts can be made from material scraps, such as construction paper or crepe paper and/or aluminum foil.

## VII - Bibliography

### A. Pupil Texts

Beauchamp, W. L., et al. *Discovering Our World - Book 3.* pp. 187 - 213, 1957, Scott Foresman. This book has an excellent astronomy review.

Frasier, G. W., et al. *Singer Science Problems - Grade 6.* pp. 290 - 339. 1959, L. W. Singer Co. This book contains an astronomy review; a discussion about the instruments for space study, rockets, satellites, some problems of space travel; and good illustrations and experiments.

### B. Supplementary Texts

Baker, Arthur, et al. *Your Science World.* pp. 217 - 225. 1955, Rand & McNally. This book has material on rockets, space stations, spaceships and exploring space.

Barnard, J. D., et al. *Science Health Safety - Book 6.* (Macmillan Science Life Series), 1959, Macmillan. This book includes material not found elsewhere, excellent activities for space travel, space station and problems of man in space.

*Basic Science Education Intermediate Series.* "Gravity" and "Sky Above Us." 1954-59, Row, Peterson. These booklets are easy reading and have good illustrations.

### C. Reference Books

Note: Several of the books suggested in this list are already out of date and have an historical interest chiefly.

Adler, Irving. *Man-Made Moons.* 1958, John Day Co. This is a detailed book about satellites.

Adler, Irving. *The Stars: Steppingstones Into Space.* 1956, John Day Co. This book is hard reading, grades 7 - 9. It has good illustrations.

Beeland, Lee. *Space Satellite.* 1957, Prentice Hall. This book explains how the first American man-made satellite will be sent into space, how special instruments will record and relay information about atmospheric conditions. It tells the story of I.G.Y., its equipment and aspirations. This book is interesting because it is possible to compare predictions to actual procedures used today.

C. Reference Books - (continued)

Branley, Franklyn. A Book of Moon Rockets for You. 1959, Crowell, New York. This easy reading book contains information about types of moon probes which are planned and includes a discussion of the specific, scientific questions which the moon probes will answer.

Branley, Franklyn. Experiments in the Principles of Space Travel. 1955, Thomas Crowell Co. This book contains explanations and experiments related to space problems. It is detailed and well done but the reading level is grades 7 - 8.

Branley, Franklyn. Exploring by Satellite - The Story of Project Vanguard. 1957, Thomas Crowell and Co. This is a beautifully illustrated book containing scenes of space and rockets. It is factual and well done. The reading level is grades 7 - 11.

*Branley, Franklyn. Mars. 1955, Thomas Crowell Co. This book has a reading level for grades 7 - 12.

Burt, Olive W. Space Monkey. 1960, John Day Co. This book traces the life of Miss Baker, the monkey which was the first living thing to journey into space and return safely. Her early life in the jungles of Peru and her training for space flight are described.

Campbell, R. W. Tops and Gyroscopes. 1959, Crowell, New York. Although this book does not contain information concerning the use of gyroscopes in space vehicles, it provides good background material for explaining the principles behind the operation of this instrument.

*Chamberlain, Joseph M. Space. 1957, Creative Educational Society. This book has a discussion of planets, stars and space.

Coombs, Chas. I. Rockets, Missiles and Moons. 1957, William Morrow. This book has good discussion of methods of transportation beyond earth's surface and what we may hope to discover when man reaches the moon. The illustrations are good. The reading level of this book is grades 3 - 6.

Coombs, Chas. I. Skyrocketing Into the Unknown. 1954, William Morrow. This book is hard reading, grades 7 - 9. The print is small but there are good illustrations.

Crosby, Alexander L. Rockets Into Space. 1959,,Random House. This book explains rockets and satellites work, what is needed to send a man into space, how space stations are built and what will be needed for the first trip to the moon.

*This reference provides information which reviews many concepts on astronomy.

C. Reference Books - (continued)

Dietz, David. All About Satellites and Space Ships. 1958, E. M. Hales and Co. This book has good description of the progress made in satellite launchings and a discussion of space medicine and effects of space travel on man's anatomy. It includes some materials on space stations and space ships. It has good illustrations and large print.

*Fenton, Carroll and Mildred. Worlds in the Sky. 1950, John Day Co. This is a well illustrated book about the stars, planets and moon. The diagrams are very useful.

*Freeman, Mae and Ira. Fun with Astronomy. 1953, Random House. This book is well illustrated with photographs. It is easy to read, containing a minimum of details.

*Freeman, Ira and Mae. The Sun, the Moon and the Stars. 1956, Random House. This is a pleasing book explaining the theoretical origin of the heavenly bodies and facts about them. Not too detailed, attractive.

*Gallant, Roy A. Exploring the Universe. 1956, Garden City Books. This book contains a good discussion of astronomy and fine illustrations. The reading level is grades 5 - 9.

*Goodwin, Hal. The Real Book About Stars. 1954, Garden City Books. This is a detailed book for youngsters about the astronomical bodies. It contains very good charts of the moon and other objects. It has a reading level of grades 5 - 8.

Holsaert, Eunice. Outer Space - A Book to Begin On. 1959, Holt. This is an easy book showing some of the basic facts and equipment for space.

Hyde, Margaret O. Exploring Earth and Space. 1957, McGraw Hill. This is a good book with a reading level of grades 4 - 7.

Hyde, Margaret O. Off Into Space. 1959, McGraw. This is an exciting book for eight to twelve year olds who may be our future space travelers.

Kay, Terence. Space Volunteers. 1960, Harper and Brothers, New York. This book contains interesting information about research on problems related to manned space travel.

Knight, Clayton. How and Why Wonder Book of Rockets and Missiles. 1960, Merrill, pp. 37 - 48 contains excellent illustrations. This book has a fairly difficult vocabulary. It covers space vehicles, problems of man in space, space stations and space travel.

*This reference provides information which reviews many concepts on astronomy.

C. Reference Books - (continued)

Lewellen, John. You and Space Neighbors. 1953, Alfred A. Knopf. This book is good for slow readers because of the fine illustrations but the information is not too practical. Vocabulary is fairly difficult.

Lewellen, John. You and Space Travel. 1958, Alfred A. Knopf. This book has excellent illustrations and is interesting and fairly informative although it does not contain too much practical application. There are pictures for slow learners but the text is for good readers.

Ley, Willy. Conquest of Space. rev. 1959, Simon & Schuster. This book describes transcontinental rockets, the topography of the moon, the major planets and their satellites and a prospective trip to the moon.

Ley, Willy. Man-Made Satellites. 1957, Golden Press. This book predicts methods of launching and uses for man-made satellites. The book is interesting because the child can make a comparison of the predictions with actual events.

Ley, Willy. Space Pilots. 1957, Simon & Schuster. This book discusses the problems of choosing and training men for space travel. It has a reading level range of grades 3 - 9. It is valuable because of the illustrations.

Ley, Willy. Space Stations. 1958, Simon & Schuster. This book tells how space stations will be used for astronomical observations and as take-off points for further space travel. It describes how they will be built, launched and maintained in orbit.

Ley, Willy. Space Travel. 1958, Simon & Schuster. This book predicts rocket age and explains how man will escape from the atmosphere and conquer open space. The suggested reading level is grades 3 - 9.

Meyer, Jerome. Picture Book of Astronomy. 1945, Lothrop, Lee & Shepard. This is a simple book telling about objects in space and space vehicles.

Moore, Patrick. The Boy's Book of Space. 1956, Roy Publishers. This book is interesting and informative but requires a good reader. The reading level is grades 7 - 11.

Neurath, Marie. Rockets and Jets. 1952, Lothrop, Lee and Shepard. This book is valuable mostly for the illustrations of the principles of engines, rockets, and parachutes.

Neurath, Marie. Speeding Into Space. 1954, Lothrop, Lee and Shepard. This book is valuable mostly for the illustrations of space vehicles and space stations.

C. Reference Books - (continued)

Newell, Homer E. Space Book for Young People. 1958, McGraw. This is a good book on astronomy. It gives facts about space, space travel, rockets and satellites. It supplies the methematics necessary for a ready understanding of space distances and rocket speeds.

Podendorf, Illa. True Book of Space. 1959, Children's Press. This book discusses what is space, where is space, what is outer space, and how and when a man will travel in space. It is a simple, easy book on space ideas.

Pratt, Fletcher. All About Rockets and Jets. 1955, Random House. This is a well illustrated book about the development and use of rockets and jets.

Pratt, Fletcher, et al. By Space Ship to the Moon. 1952, Random House. This is a beautifully illustrated book with good text about a trip to the moon. It is one of the very best on the subject but it is hard reading.

Ross, Frank, Jr. Space Ships and Space Travel. 1954, Lothrop, Lee and Shepard. This is a detailed book about the history of space travel and modern problems on the subject. It contains interesting historical photographs.

*Ruchlis, Hy. Orbit: A Picture Story of Force and Motion. 1958, Harper and Brothers. This is a well written, illustrated book related to flight and space which shows Newton's Laws of Motion in action.

*White, Anne Terry. All About the Stars. 1953, Random House. This book contains much information about astronomy and includes a chapter on what life there may be on Mars. The reading level is grades 4 - 9.

The second experimental edition of the guide, Literature in the Junior High School, contains a bibliography on pages 56 - 58 on "Man's Invasion of Space." The bibliography intended for grade nine children contains science information and science fiction books. Contact the grade nine literature teacher in the nearest junior high school to make arrangements to borrow the guide.

Note: Additional Space Travel information may be secured by writing the following:

National Aviation Education Council
1025 Connecticut Avenue, N. W.
Washington 6, D.C.

National Aeronautics and Space Administration
Washington 25, D.C.

*This reference provides information which reviews many concepts on astronomy.

## FILMS

| | |
|---|---|
| Earth Satellites:<br>Explorers of Outer Space | EBF - Color - 17 min.<br>Excellent film. Covers application of natural laws in putting satellites into orbit (Sputnik I, Explorer I, Vanguard, Jupiter). Good explanation of balance between centrifugal force and gravity. Information on tools used by astronomers, first satellites, use of satellites, training of men for space travel and building a space station and space ship in space, itself. |
| Gravity | Coronet - B/W - 10 min.<br>Well done - simple. Covers relationship of mass and distance to gravity. Some mention of space travel. |
| Man in Space | Walt Disney - Color - 30 min.<br>Effective presentation of man's problems and needs in going into space. Holds children's interest, stimulates imagination and generally well done. |
| Mars and Beyond | Walt Disney - Color - 30 min.<br>Excellent information on space ships, surface features and possibility of life on Mars. Brings in contributions of Galileo, Von Braun, Herschel and Copernicus. Has high interest value for children. |
| Our Mr. Sun* | N.W. Bell Telephone - Color - 60 min.<br>Long, but well done with story narrative acted by Richard Carlson. Comes in two reels, each approximately 30 minutes in length so could show first part, discuss; then, go on to second reel. Shows need for sun for existence of life on earth. |
| Planets in Orbit* | EBF - B/W - 10 min.<br>Covers laws of Kepplon and other historical data in this area (theories of Ptolemy, Copernicus, Keppler, Brahe). Very good explanation of relationships in solar system between sun and planets, how planets rotate around sun, revolve on axis, etc. Shows how Galileo came to invent the telescope, improvements made by Keppler and gives tables for movements of the stars, moons and planets. |

*This reference provides information which reviews many concepts on astronomy.

## Films - (continued)

| | |
|---|---|
| Realm of the Galaxies* | Educational Testing Service - Color - 20 min.<br>Well done but for good students - would need thorough discussion following viewing. Covers corona of sun, size of stars, development and use of different kinds of telescopes, what the universe contains, shapes and sizes of galaxies and how the observatory at Palomar operates. Particularly good in showing operation of modern observatory and work of astronomers. |
| Research by Rockets | McGraw Hill - Color - 27 min.<br>Research and power of rockets is stressed and their functional application as devices to permit man to extend his knowledge of his planet and the cosmos thematic. Difficult - use for summary activity. |
| Satellites: Stepping Stones to Space | Film Associates of California - Color - 17 min.<br>Excellent coverage of what satellites are and why they are important to us; shows instruments carried in satellites and explains use of each with diagrams. Describes how Explorer I was put in orbit, why satellites stay up. Holds interest and good for elementary group. |
| The Solar Family* | EBF - B/W - 10 min.<br>Describes theories about origins of the solar system. Vocabulary is quite difficult so needs considerable discussion. Shows size of planets and their orbits around the sun. Also, portrays physical conditions probable on Mars and Saturn, the asteroid belt and the orbit of Halley's comet. |
| The Solar System* | Coronet - B/W - 10 min.<br>Very good. Shows distance of planets from sun, relative size of planets and sun and how planets stay in orbit around the sun. |
| A Trip to the Moon | EBF - Color - 16 min.<br>Describes the trip of an imaginary rocket to the moon. High interest - facts necessary for navigation to moon and know conditions of moon's surface. |

*This reference provides information which will review many concepts on astronomy.

## VIII. SUMMARY LIST OF SUGGESTED EQUIPMENT AND SUPPLIES

aeneroid barometer
alcohol lamp
aluminum foil
aluminum sheets
apple
aquarium
asbestos sheets
automobile
automobile tire

baking soda
ball
ball bearing
ball, sponge rubber, 1" diameter
balloon
barrel
bathroom scales
bead, white, small
beakers, 250 m
bearing, steel ball
bicycle
bicycle tire pump
bit
bits, for metal
black coat
blindfolds
bolts, aluminum
board, shelf from bookcase
board, 3/4" x 3' x 3', plywood
book
book, "Who's Who in Biological Science"
book, "Who's Who in Physical Science"
book, "Who's Who in America"
bottle, smooth cylindrical shape, clear glass
bottle, tall, small mouth, with cap
brace
bricks
brick, heavy construction
broom
burette clamp

"C" clamp
cake pan
camera, with shutter speed of 1/100 seconds or faster
candle
cans, frozen juice
cardboard, 2' x 3'
cardboard, corrugated

carton, 12" x 18" approximately
cartridge
cat fur, piece
catcher's mitt
chairs
chalk
chalkboard erasers
circular cardboard carton
(used for shipping dry chemicals)
clips, alligator
clippings
clock,
clock, with second hand
cloth, large enough to cover clock
clothes hanger
clothes pins (not spring type)
clothing
coffee can
colored sticker
coleus plants
compasses
corn starch
cork to fit bottle
cotton flannel board
crayons

deep armchair
desks
dish pan
ditto fluid can with cover
doll, about 24" long
dowel rod, 1/2" diameter, 6" long
dowel rod, 1/4" diameter, 12" long
drill

electric fan
electromagnet
electroscope
eraser, rubber

firing pin for cartridge
fish line, 5' long
flashlight
flask, Florence 500 ml, Pyrex
flax
fork, metal
frying pan, cast iron, 10" diameter
frying pan, stainless steel, 10" diameter
funnel

glass jar, wide mouth, one gallon
glass tubing
globe, terrestrial
glue
graph paper
gymnasium mat
gyroscope

hack saw
hair pins
hammer
handkerchief
hardware cloth
hot pad or oven mitten

ice
ice cube

jar cap

knife
knife, switch

ladder, 5'
large jar with cover
liquid petroleum burner

magazines, recent
magnets, bar, with different strengths
mail tube or other cylindrical object
marbles
marking pen
matches
medicine dropper
merry-go-round in park playground
metal working file (rasp)
milk
mirror, pocket sized
model rocket
model of a satellite
modeling clay
motion picture projector, 16 mm

nail, brad
nails, finishing
needle
newspaper
newspapers, recent

one hole rubber stopper
oven
overcoat

paint, black
paper
paper clip
paper cups, cone shaped
paper fastener, 1/2"
paper sack
Park's Satellite Rocket
paste
pebbles
pen
pencil
pencils, colored
pennies
periodicals
physical features map of Minnesota
physical features map of the United States
phonograph turntable
pin
ping pong ball
plaster of Paris
pliers
pocket mirror
portable steamer
potato, very small
printed page from newspaper
projection screen
pulley
punk or twist of paper

rectangular iron support
reference materials (recent periodicals, textbooks, encyclopedias)
refrigerator
ring clamp
roller skate
rope, 6' long
rubber ball, attached to an elastic string
rubber band
rubber hose
rubber rod
ruler

sand
sandpaper
scale model of a space capsule
scissors
scrapbook
scraps of wood, cloth, elastic, wire
screen, window about 6" x 18"
screw eyes
screw, round headed 1/2" long
sheet of paper, 8" x 11"
shoe polish, black
sipper straw, paper or plastic
slide projector
small metal can (tooth powder, spice)
soda pop bottle
spring, from screen door
spring, scale
stick
stop watch
storage battery, 6 volt
stovepipe wire
string
student desk
swing

table
tape, collephane
tape, cellulose
tape, masking
tape measure
teaspoon
thermometer, Fahrenheit
thread
thumb tacks
tin can
tin snips
top
towels
transparent material (plastic sheets, cellophane, Saran Wrap)
triangular file

vinegar

wagon
washers, 1/2" inside diameter
watches
water
wax, "Sealstix"

weather balloons, 30" diameter
weight
wheat paste
white mouse
wire, copper #18
wire, heavy
wire, iron #18
wire, piano
wire gauze
wood bits, 9/16" and 18" diameter
wood block

yardstick

MINNEAPOLIS PUBLIC SCHOOLS
Science Department

## SOME ASTRONOMICAL FACTS AND APPROXIMATIONS FOR TEACHING

| FACTS | Mercury | Venus | Earth | Mars | Jupiter | Saturn | Uranus | Neptune | Pluto |
|---|---|---|---|---|---|---|---|---|---|
| Average distance from sun in millions of miles. | 36* | 67.2 | 93 | 141.5* | 483.3 | 886.1 | 1,782.8 | 2,793.5 | 3,675* |
| Relative for class use. Earth to moon—240,000 miles | 4" | 8" | 1' | 18" | 5' | 10' | 20' | 30' | 40' |
| Diameter in miles. | 3,000 | 7,600 | 7,900 | 4,200 | 88,700 | 75,100 | 30,900 | 33,900 | 3,500 |
| Relative for class use. (Sun—864,000 miles-108" Moon—2,000 miles-1/4") | 1/3" | 3/4" | 1" | 1/2" | 11" | 9" | 4" | 4½" | 1/2" |
| Known satellites | 0 | 0 | 1 | 2 | 11 | 9 | 5 | 2 | 0(?) |
| Orbital velocity in miles per second | 29.7 | 21.7 | 18.5 | 15.0 | 8.1 | 6.0 | 4.2 | 3.4 | 2.7? |
| Time required to travel around the sun (period of revolution in earth years) | 0.24 | 0.615 | 1 | 1.88 | 11.86 | 29.5 | 84.0 | 164.8 | 248.0 |
|  | (88 days) | (225 days) | (365¼ days) | (687 days) |  |  |  |  |  |
| Length of day (Period of rotation) | 88 days | ? | 1 day | 24 hr. 37 min. | 9 hr. 55 min. | 10 hr. 14 min. | 10 hr. 40 min. | 15 hr. 40 min. | ? |
| Gravity at surface based on the earth as 1 | 0.27 | 0.87 | 1 | 0.38 | 2.64 | 1.17 | 0.92 | 1.12 | 0.9(?) |
| Surface escape velocity in feet per second (Moon=1,800) | 13,600 | 33,600 | 36,700 | 16,700 | 197,000 |  |  |  |  |
| Minimum launching velocity in thousands of feet per second | 44 | 38 |  | 38 | 46 | 49 | 51 | 52 | 53 (Sun=54) |
| Transit Time | 110 days | 150 days |  | 260 days | 2.7 years | 6 years | 16 years | 31 years | 46 years |

* Elliptical Orbits

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## TWENTY STARS OF THE FIRST MAGNITUDE
(in order of brightness)

| Star | Distance in Light Years | Constellations |
|---|---|---|
| Sirius | 8.3 | Canis Major ("The Great Dog") |
| Canopus | 200 | Argo ("The Ship") |
| Alpha Centauri | 4.3 | Centaurus ("The Centaur") |
| Vega | 26 | Lyra ("The Lyre") |
| Capella | 50 | Auriga ("The Chariot") |
| Arcturus | 40 | Bootes ("The Herdsman") |
| Rigel | 600 | Orion ("The Hunter") |
| Procyon | 10.4 | Canis Minor ("The Little Dog") |
| Achernar | 70 | Eridanus ("The River") |
| Beta Centauri | 90 | Centaurus("The Centaur") |
| Altair | 16 | Aquila ("The Eagle") |
| Betelgeuse | 300 | Orion ("The Hunter") |
| Alpha Crucis | 100 | Crux ("The Cross") |
| Aldebaran | 60 | Taurus ("The Bull") |
| Pollux | 32 | Gemini ("The Twins") |
| Spica | 200 | Virgo ("The Virgin") |
| Antares | 400 | Scorpio ("The Scorpion") |
| Fomalhaut | 24 | Piscis Australis ("The Southern Fish") |
| Deneb | 400 | Cygnus ("The Swan") |
| Regulus | 60 | Leo ("The Lion") |

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APPENDIX C

# CHANGE OF WEIGHT WITH CHANGE OF DISTANCE FROM THE CENTER OF THE EARTH

This table assumes that a 100 pound boy on the surface of the earth is 4,000 miles from the earth's center of mass. The table also assumes that, as the 100 pound boy moves away from the earth, no other object exerts a gravitational attraction on the boy.

| Distance from center of earth in miles | | Weight in pounds |
|---|---|---|
| 4,000 | = | 100 |
| 5,000 | = | 64 |
| 6,000 | = | 44 |
| 7,000 | = | 33 |
| 8,000 | = | 25 |
| 9,000 | = | 20 |
| 10,000 | = | 16 |
| 12,000 | = | 10 |
| 16,000 | = | 6.3 |
| 20,000 | = | 4.0 |
| 30,000 | = | 1.8 |
| 40,000 | = | 1.0 |
| 50,000 | = | .64 |
| 60,000 | = | .44 |
| 70,000 | = | .33 |
| 80,000 | = | .25 |
| 90,000 | = | .20 |
| 100,000 | = | .16 |
| 200,000 | = | .04 |
| 300,000 | = | .018 |

# A MATHEMATICAL COMPARISON OF THE EARTH'S NATURAL AND PROPOSED ARTIFICIAL SATELLITES

## I. Our Moon

From Sir Isaac Newton's third law of motion we learn that "to every force or motion there is an equal and opposite force or motion." It is believed that the reason any satellite stays in its nearly circular orbit, rotating around a planet, is because the gravitational force (G.F.) or centripetal force inward is exactly equal at all times to the centrifugal force (C.F.) outward.

$$G.F. = \frac{KM.M_2}{D^2} \quad = \quad C.F. = \frac{M_2V^2}{D} \qquad \text{(A)}$$

where

$K$ = a constant

$M_1$ = mass of the earth

$M_2$ = mass of the moon

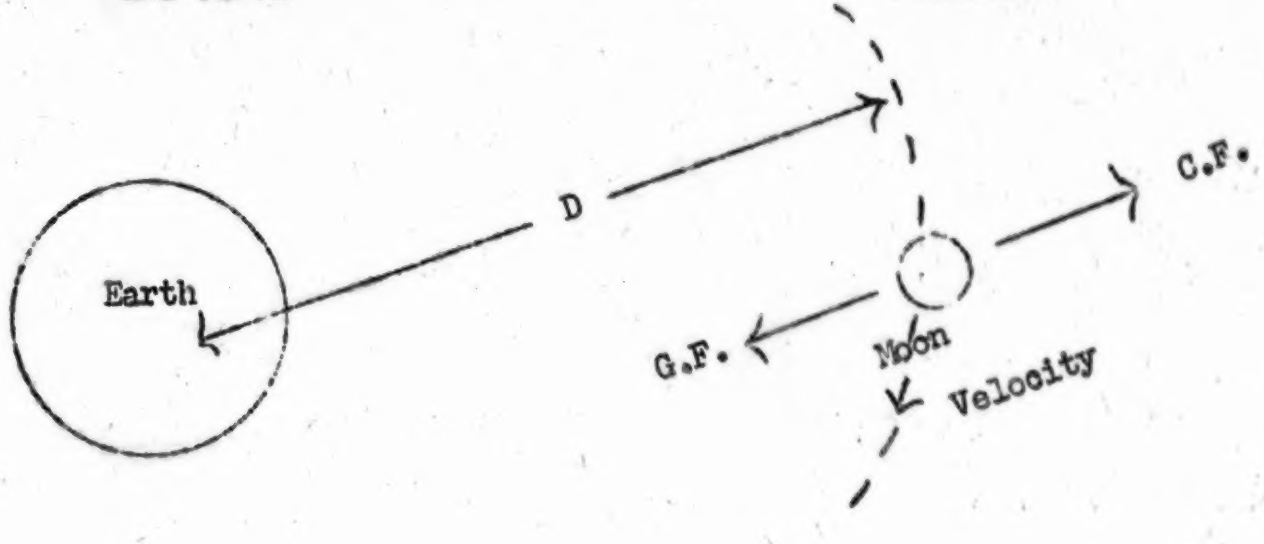
$D$ = distance between the centers of the moon and earth

where

$M_2$ = mass of the moon

$V$ = velocity of the moon

$D$ = distance of moon's center to center of rotation (earth's center)



$$\frac{K\ M_1\ M_2}{D^2} \quad = \quad \frac{M_2\ V^2}{D}$$

Cross multiply:

$$K\ M_1\ M_2\ D \quad = \quad M_2\ V^2\ D^2$$

Divide both sides by $M_2D$:

$$K\ M_1 \ = \ V^2D \quad \text{or} \quad V^2 = \frac{K\ M_1}{D} \qquad \text{(B)}$$

By this means we have excluded the weight of the moon from our equation. From Newton's first law of motion we know that the gravitational force (G.F.) on any body on the earth's surface is the product of its mass and acceleration; G.F. - m a. Substituting for G.F. in the left hand equation (A) above, we have:

$$m\ a - \frac{K\ M_1\ M_2}{D^2}$$

Solving for $K\ M_1 = a\ D^2$

We know that the acceleration "a" of any freely falling body near the surface of the earth is about 32 ft/sec/sec and D in this case is the diameter of the earth or 4000 miles .5280.

Therefore $KM_1 = 32\ (4000.5280)^2$.

We now can substitute in equation,

$$\text{(B)}\quad V^2 = \frac{32.(4000.5280)^2}{D}$$

Since the distance, D, from the center of the moon to the center of the earth averages about 61 times the radius of the earth, then D = 61.4000.5280.

$$\text{Therefore } V^2 = \frac{32.(4000.5280)^2}{61.4000.5280} = \frac{32.4000.5280}{61} = 11{,}080{,}000 = 11.08 \times 10^6$$

$$V = 11.08 \times 10^6 = 3.3 \times 10^3 \text{ or } 3300 \text{ ft/sec.}$$

Since we know the velocity, V, of the moon along its orbit and the circumference of the orbit, ($2\ \ r = 2\ .\ 3.1416\ .\ 61\ .\ 4000\ .\ 5280 = 8.1 \times 10^9$) we can determine the time the moon requires to go around the orbit by, circumference = Vt,

$$t = \frac{Cir}{V} = \frac{8.1x10^9}{3.3x10^3} = 2.43x10 \text{ seconds}$$

which is $\frac{2.43 \times 10^6 \text{ seconds}}{24} = 675$ hours or $\frac{675}{24} = 28.2$ days

## II. Proposed Artificial Satellite

As we look at equation (A) and/or (B) we can deduce that if an artificial satellite is to be near enough to be observed from the earth, its velocity will have to be much greater. As the value of D becomes smaller the value of V must become larger.

Let us suppose we plan to project a satellite into an orbit at 300 miles from the earth. Then D = 300 + 4000 = 4300 miles. When we introduce this into the equation (B) we will have

$$V^2 = \frac{32\ (4000.5280)^2}{4300.5280} = \frac{32.4000^2\ .5280}{4300} = 630 \times 10^6$$

$$V = 630 \times 10^6 = 25.1 \times 10^3 = 25{,}100 \text{ ft/sec}$$

Again calculating the time for rotation at this velocity

$$t = \frac{Cir}{V} = \frac{2.3.1416.4300.5280}{25.1 \times 10^3} = \frac{142 \times 10^6}{25.1 \times 10^3} = 5650 \text{ seconds or}$$

$$\frac{5650}{60} = 94 \text{ minutes}$$

Any other height of satellite can be figured but it must be sufficient to clear our mountains and of course air frictional heat might burn up a very fast satellite.